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Proceedings of the First Triservice Conference on Rotary-Wing Spatial Disorientation: Spatial Disorientation in the Operational Rotary-Wing Environment

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Several recent studies at the U.S. Army Aeromedical Research Laboratory (USAARL) and the U.S. Army Safety Center (USASC) have highlighted the significant contribution of Spatial Disorientation (SD) to helicopter accidents. In the U.S. Army the cost can be approximated at $58M and 14 lives each year. Following some local training initiatives by USAARL and the U.S. Army School of Aviation Medicine (USASAM), the first Triservice Symposium on Spatial Disorientation in Rotary-Wing Operations was held from 24 September 1996 through 26 September 1996 at USASAM. This symposium sought to address three main areas: the seriousness of the SD hazard; current methods to control the hazard; and the associated safety and risk management concerns. This report contains the proceedings of the symposium. The symposium was considered to be a success in raising the awareness of the impact of SD on rotary-wing flying operations in the aeromedical and safety communities of the services. It was clear that SD imposes a particular hazard to rotary-wing operations which differs in many respects to that experienced by fixed wing operators. There was unanimous agreement that initiatives to overcome the problem must be made. In order to maintain the impetus established by the symposium and secure funding

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for the various initiatives, the report contains a memorandum detailing the important factors and makes recommendations for future activity in the area. Work is required in education, training, research, and equipment procurement. Control factors are discussed and recommendations made according to whether the approach should be solely directed towards the U.S. Army, or on a triservice basis.

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Introduction

The first triservice conference on rotary-wing spatial disorientation (SD) entitled "Spatial Disorientation in the Operational Rotary-Wing Environment" was sponsored by the U.S. Army School of Aviation Medicine (USASAM), Fort Rucker, Alabama, from 24 through 26 September 1996. Lieutenant Colonel Malcolm Braithwaite of the U.S. Army Aeromedical Research Laboratory (USAARL) was asked to chair the conference which was aimed at the operational needs of the deploying flight surgeon and safety officer. The conference focused on three main areas: the seriousness of the problem of SD in rotary-wing operations, what the services are doing about the SD problem, and safety issues surrounding SD.

This report records the proceedings of the conference either in the form of edited spoken text or copies of projected slides, and makes recommendations about the initiatives that should be taken to control the hazard of SD. The conference agenda is at table 1. Details of technical presentations appear in the following sections. A list of attendees and introductory remarks about the speakers are at appendices A and B, respectively.

Table 1.
Conference agenda.

Monday, 23 September 1996

	Travel, check in to BOQ

Tuesday, 24 September 1996

0800-0900	Registration, USASAM, Bldg 301, X-110
0800	Speakers meet for coordination and instruction on visual aids
0900-0915	Opening Remarks - LTC Toomey, Assistant Dean USASAM
0915-0945	Keynote Speaker - BG Konitzer, Commander USASC
0945-1000	Administrative Announcements - CPT Schwarz/Lt Col Braithwaite
1000-1030	Midmorning Break and sign up for activities
1030-1145	Revision of the Physiology of SD and "Puzzling Perceptions" video LTC Braithwaite
1145-1300	Lunch
1300-1330	Impact of SD on Army RW Opns - LTC Braithwaite/LTC Murdock
1335-1405	Impact of SD on USN RW Opns - CAPT Almond
1405-1415	Afternoon Break
1415-1445	Impact of SD on USMC RW Opns - LTC Mason
1450-1520	Impact of on USAF RW Opns - LTC Johnson/LTC Hill
1525-1550	Discussion
1830	Icebreaker (Officers club)

Table 1.
Conference agenda (continued).

Wednesday, 25 September 1996

0800-0830	Training Initiatives to overcome SD in the Army - CPT Thompson/ LTC Braithwaite
0835-0855	Training Initiatives to overcome SD in the USAF - Sqn Ldr Maidment/LTC Hill
0900-0920	Training Initiatives to overcome SD in the USN - CAPT Clarke
0925-0945	Training Initiatives to overcome SD in the USMC - LTC Mason
0945-1000	Discussion
1000-1010	Midmorning Break
1010-1030	Technology Initiatives - Vibrotactile Interface - Dr Raj
1035-1055	Technology Initiatives - Novel Display - LTC Braithwaite
1100-1120	Technology Initiatives - 3D audio - Dr Chelette
1120-1230	Lunch
1230-1245	Classification of the Army SD mishap - LTC Murdock
1250-1305	Classification of the USN/USMC SD mishap - CAPT Almond
1310-1325	Classification of the USAF SD mishap - Mr Ercoline
1330-1345	Proposed SD mishap investigation appendix - LTC Braithwaite
1345 -1400	Syndicate practice using SD mishap investigation appendix
1400-1415	Afternoon Break
1415-1430	Review results of syndicate work - LTC Braithwaite
1430 -1445	Fielding the appendix
1445-1500	FINAL DISCUSSION - LTC Braithwaite
1510-1540	TBD - Mr Novosel

Thursday, 26 September 1996

0800-1200	Spatial Disorientation Demonstration Sortie (USAARL Helipad)

Keynote speaker - BG Thomas J. Konitzer, Commander, U.S. Army Safety Center

Brigadier General Konitzer's address is not recorded in full as it contained sensitive material, but some of his pertinent remarks are made below.

Eighty percent of mishaps are caused by human factors. We have got to be able to drive that down to make an impact on our war fighting capability. The Chief of Staff, in a recent visit to the Safety Center, said, "as the Army gets smaller, through risk management and other initiatives, we have got to look at how we can preserve the force better."

We need to establish how many of our accidents are due to SD. The work that has been done at USAARL over the last few years has highlighted the seriousness and magnitude of this particular problem. The average annual loss from SD is about 16 lives and $60 million. That is unacceptable. We have reduced our accident rate to less than one Class A accident per 100,000 flying hours, but we should not rest on our laurels and feel satisfied that losing even one life or aircraft is acceptable. We have got to understand SD better. There are many crew coordination factors, and night vision goggles (NVGs) and forward looking infrared (FLIR) flight increases the risk of having an accident by 10-15 times. Not only does it cause accidents, but SD has an important effect on mission readiness and accomplishment, and the ability to be an effective part of the fighting team.

Everyone is susceptible to SD. If pilots feel that it's not going to happen to them, then we have got to do a better job of increasing the awareness and driving home the point that SD is a serious problem. Controls can be placed in relationship to a potential hazard. This can be done for SD at several places, from training through procedural changes to technological advancements. We are not giving enough attention to SD during our initial entry rotary-wing (IERW) courses. We don't spend a lot of time addressing SD during crew coordination training. Research is sporadic and there is probably not the cohesive effort that is required. There are very few pieces of equipment that have been introduced to deal with the problem of SD. The bottom line on the effectiveness of controls today is "not very good."

In conclusion, SD has not been given enough attention over the years, although I recognize the effort by a few. Because of the jointness that we have here today, I submit that this is the forum to determine the efforts that we need to share data and establish long term working groups that can continue to deal with this problem. The areas of education, training, research and equipment all need to be addressed. Your challenge is to put some "meat on the bones" and to address the "how to" better, both to recognize it and how to get out of it.

Introduction to the symposium

Lieutenant Colonel Malcolm Braithwaite welcomed the attendees and made the following remarks.

In 1993 a combined Aviation Medicine/Safety Center symposium on SD was held at Pensacola. That conference was well attended and much agreement about collaboration between the service research agencies was made. Following the conference, a memorandum signed by both the Army and Navy Safety Center commanders was distributed to the Aviation Command, the First Aviation Brigade, and the Aviation Training Brigade. Many recommendations were made. However, although much has gone on in the research field, it has only been in the last year that some of the operational issues have been addressed. This has been mainly in the following areas:

- Agreement of a common academic definition for SD.
- A standard of aircrew training in SD.
- Attention to standardizing data on SD related accidents.

We have much more progress to make on this important issue, and so, as a member of the triservice working group on situational awareness and SD, I was pleased to be asked to chair this symposium sponsored by USASAM. You are here because we feel that in your role as flight surgeons and safety officers, you have an enormous amount to offer to combat the problem of SD. We have representation from many of the aviation brigades and our sister services, and even international interest from Australia and the Netherlands.

We think that we have put together a program that hopefully not only will educate you, but will also stimulate some friendly discussion and debate within this forum. The aim is to galvanize you, once you return to your units, into collectively helping the effort to enhance flight safety and operational effectiveness by tackling the problem of SD. This is a symposium (Webster's definition is "a meeting or conference for discussion of some topic," although I prefer one of the alternatives - "a convivial meeting for drinking, music and intellectual discussion {in ancient Greece}"). We do, therefore, encourage audience participation. We will be publishing the proceedings of this symposium.

Revision of the physiology of SD and "Puzzling Perceptions" video

This presentation is not recorded in these proceedings. The physiology of SD can be found in standard textbooks of aviation medicine, for example:

Fundamentals of Aerospace Medicine, ed. DeHart, Lea and Febiger, Philadelphia, 1985 (ISBN 0-8121-0880-9). This publication is also U.S. Army FM-8.

Aviation Medicine, ed. G. Dhenin, Tri-Med Books, London 1978.

United States Army Aviation Medicine Handbook, ed. Crowley, Third Edition 1993.

Aeromedical Training for Flight Personnel, FM 1-30, (under review).

The video "Puzzling Perceptions" is the most recent British training film on SD. It was extremely well received by the conference audience. The video, reference number AF 9467, was kindly loaned by the United Kingdom Services Sound and Vision Corporation (SSVC). Copies may be purchased from SSVC at the following address: SSVC Multimedia, Chalfont Grove, Narcot Lane, Chalfont St. Peter, Gerrards Cross, Buckinghamshire, SL9 8TN, United Kingdom.

Session 1: The impact of SD on rotary-wing operations

Introduction

This session is going to cover the impact of SD on rotary-wing operations. You were reminded in the physiology revision session that aviators suffer SD because of the innate limitations of their orientation senses in flight and the generation of erroneous visual and vestibular cues. This is because we are human, and ever since man has been flying, that has been the weakest link.

Modern aircraft are potent and expensive weapon systems. Commanders can ill-afford high losses from non-military causes such as SD. So how big is the problem? We are going to hear from each of the services about their experiences. We all know SD is a problem, but most research deals with fixed wing issues. I know it has concentrated your minds because we rarely concentrate on the rotary-wing aspect, but I am sure that by the end of the session, we will see just how big a problem it is and the common areas between the services that we can attack.

The impact of SD on Army rotary-wing operations

Lieutenant Colonel Ed Murdock opened this session. His presentation is not recorded in these proceedings, as it contained sensitive material. Lieutenant Colonel Malcolm Braithwaite then presented details of recent epidemiological research performed at USAARL. The text and figures are reproduced below.

Introduction and methods

The aim of this presentation is to show you some of the results of an analysis of Army helicopter accidents that was originally compiled by my predecessor, Colonel Simon Durnford. I have recently updated the survey to include the fiscal years 1993 to 1995, but most of the findings and conclusions have remained the same. It will be demonstrated that SD has a significant impact on military operations, and also give the reader an idea of the "typical" Army SD helicopter accident.

Previous studies in all services have suggested that the contribution of SD to aircraft accidents is probably underestimated. So, in order to gain a better idea of the significance of this problem, we examined the accident data and summaries from the Army Safety Center of all Class A through C accidents from fiscal year 1987 through 1995. Three flight surgeons acting independently reviewed each accident summary and extracted information. They were asked to classify the accident according to the role of SD and then to answer various questions.

We used the definition of SD as follows: "A term used to describe a variety of incidents occurring in flight where the pilot fails to sense correctly the position, motion or attitude of the aircraft or of himself within the fixed co-ordinate system provided by the surface of the earth and

the gravitational vertical. In addition, errors in perception by the pilot of his position, motion or attitude with respect to his aircraft, or of his own aircraft relative to other aircraft, may also be embraced within a broader definition of SD in flight." This excluded getting lost, but included contact with an obstacle known to be present but misjudged to be sufficiently separated from the aircraft. Contact with an obstacle whose presence was simply unknown was not considered to be SD.

Results of the study

The classification of SD that we used is shown in figure 1. Of 993 Class A through C accidents during the period, 970 were entered into the study. The remainder were either simple listings of "other aircraft" involved in multiple-aircraft accidents, or had been reclassified lower than Class C by the time computer analysis began. We regarded SD as having a significant impact on the accident sequence if it was classified either as major or contributory. Therefore, 30 percent of all accidents involved SD (figure 2). Ninety percent of the SD accidents were type 1 SD (unaware of the error), and eight percent were type 2 (awareness of a conflicting input of correct and incorrect perception of orientation).

Classification of Accidents

Major

all other contributory factors would normally have been overcome without mishap.

Contributory

other contributory factors would have led to a mishap in any case - but SD made the accident sequence more difficult to deal with or the outcome more severe.

Incidental

SD occurred but did not affect the outcome of the accident ..

SD did not occur or unknown

Figure 1. Classification of accidents.

SD accidents had a particularly severe outcome. Thirty-six percent of SD accidents were Class A compared to 18 percent of non-SD accidents (figure 3). The total cost of the 30 percent of all accidents in which SD was implicated was almost as much as the 70 percent in which it was not (figure 4). The average cost of the SD accidents was significantly greater than the average cost of non-SD accidents. One hundred and ten lives were lost in 291 SD related mishaps compared to 93 in 679 other accidents (figure 5). Again, the average number of lives lost per SD accident was significantly higher than the average per non-SD accident. Eighty-four of the SD deaths (three quarters) occurred in night accidents. It must be concluded, therefore, that a reduction in the SD accidents rate would save a disproportionate amount of lives and money.

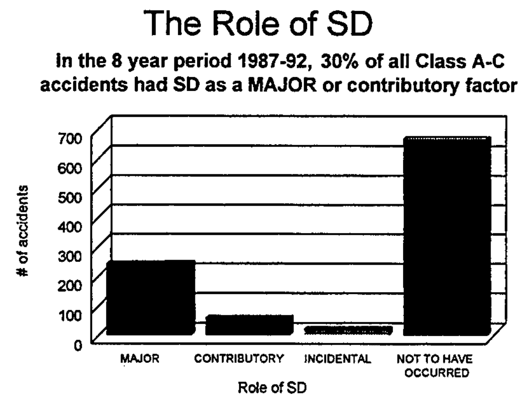


Figure 2. The role of SD.

The comparative severity of SD and non-SD accidents

- 36% of SD accidents were Class A
- 18% of non-SD accidents were Class A

Figure 3. The comparative severity of SD and non-SD accidents.

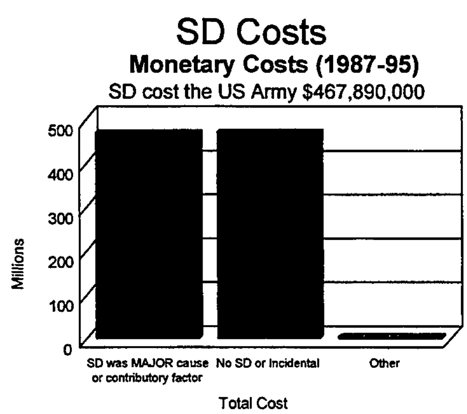


Figure 4. SD costs (monetary).

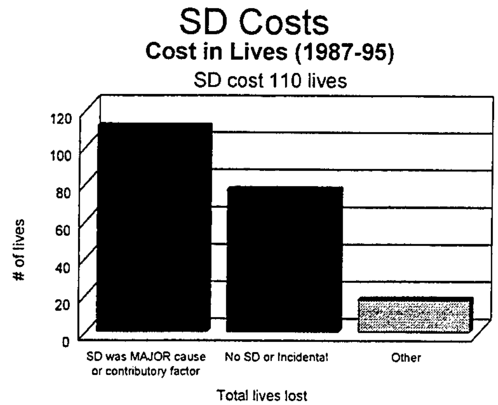


Figure 5. SD costs (lives lost).

Type of flight

Only 13 percent of non-SD accidents occurred during night vision device (NVD) use, whereas 46 percent of SD accidents involved aircrew using NVDs. The increased risk of SD with NVDs can be illustrated in the accident rates for the various types of flight (figure 6). This is hardly a surprise, as flying is a highly visual occupation and if vision is degraded, then SD becomes more likely. SD has long been a recognized shortcoming to the otherwise enormous advantage of NVDs. Although the clarity of the night device image is improving with technology, limitations remain, particularly from the restricted field of view.

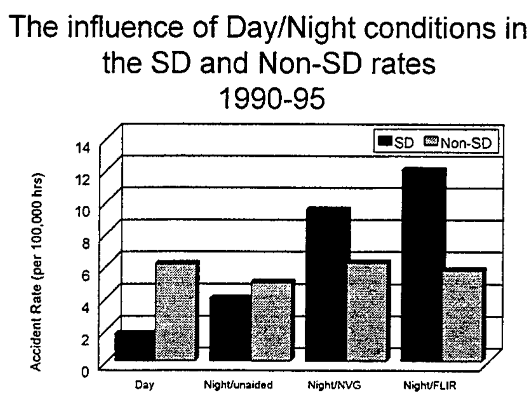


Figure 6. The influence of day/night conditions in the SD and non-SD rates.

In figures 7 through 9, the SD accidents are broken down by aircraft according to the type of flying: day and night; and night, both unaided and aided. The percentages relate to accidents caused by SD for that helicopter. The average rate for that type of flying is shown by the horizontal line. Statistical testing indicates that only the UH-60 and AH-64 SD rates are

significantly higher than the average. Both of these helicopters have features that might be considered as potential factors in SD: the UH-60 has large windshield pillars blocking a part of the view from the cockpit, and the AH-64 has the FLIR night imaging system. There are, however, other potential factors at play, such as combat roles, and it would be rash to draw conclusions at this stage, other than aircrew flying today's missions in modern aircraft appear to be at just as great a risk of SD as before. For NVG flight, the OH-58 A/C and the UH-1 feature above average SD accident proportions, and of particular note is that 64 percent of AH-64 FLIR accidents were attributed to SD.

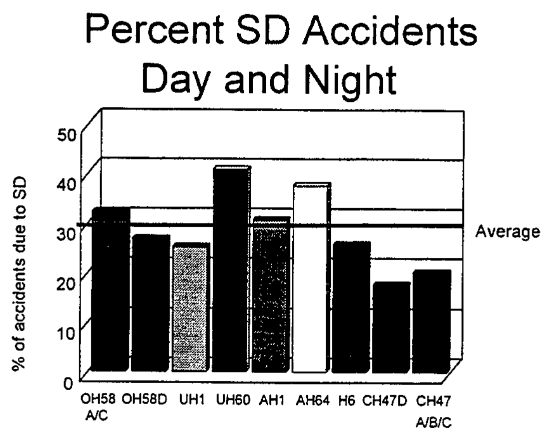


Figure 7. Percent SD accidents - day and night.

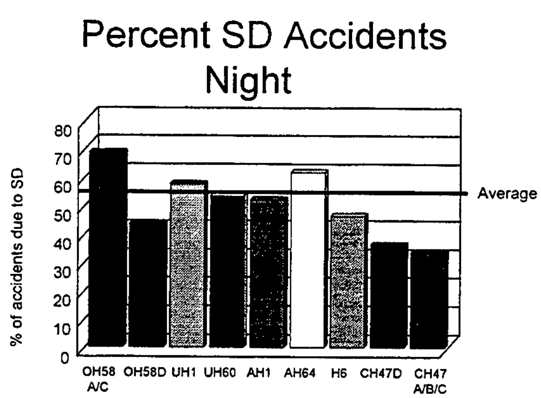
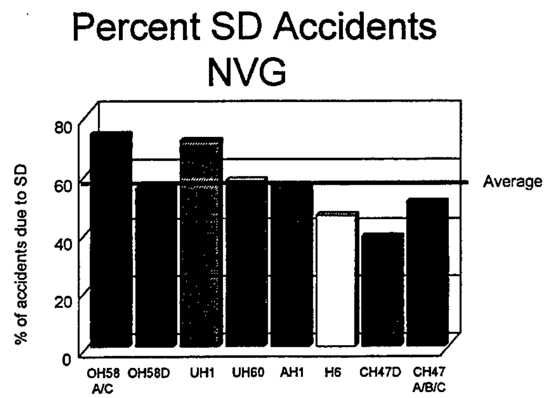


Figure 8. Percent SD accidents - night.



63.4% of FLIR accidents were due to SD.

Figure 9. Percent SD accidents - NVG.

Comparisons between aided and unaided night flight are not easy. Although unaided flights are flown at greater altitude and may be technically more simple, they are essentially flown "blind," very like instrument flight rules (IFR) conditions. On the other hand, NVD flights are flown in a more challenging fashion near to the ground, and the NVDs themselves may, of course, limit perception and even create illusions. It can be seen that our results indicate that using NVDs increases the risk of SD.

Flight hours data

As well as looking at the proportion of accidents due to SD, we have flying hours data for all flying, and since 1990, this is broken down into daytime flying and the various forms of night flying for each type of aircraft. Where there are enough accidents to analyze, we can investigate these rates. In figure 10 it can be seen that SD accidents (broken line) represent an almost constant proportion of the overall (solid line) Class A through C accident rate. Although there is a downward trend after the peak during Operation Desert Storm, matters are not really getting better. Figure 11 again shows the overall rate and then the rate broken down into the various types of flight for all helicopters. The night aided SD rate closely follows the overall accident rate for this category.

If we break the rates down to individual types of aircraft, some differences become very striking (figure 12). As a comparator, the overall rate is in the top left. The other graphs show total day and night rates for the OH-58 A/C models, the OH-58 D and the AH-64. It is plain to see that the OH-58 D and the AH-64 have both a higher overall accident rate and an equally high SD rate.

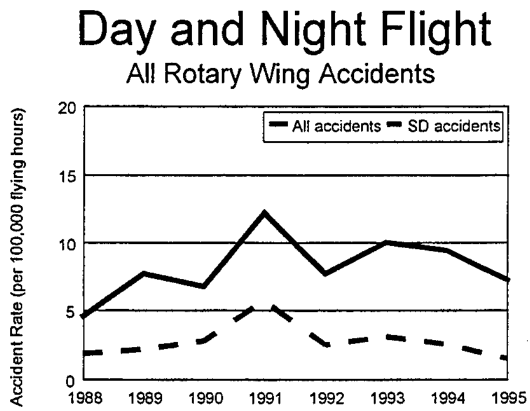


Figure 10. Total accident rates.

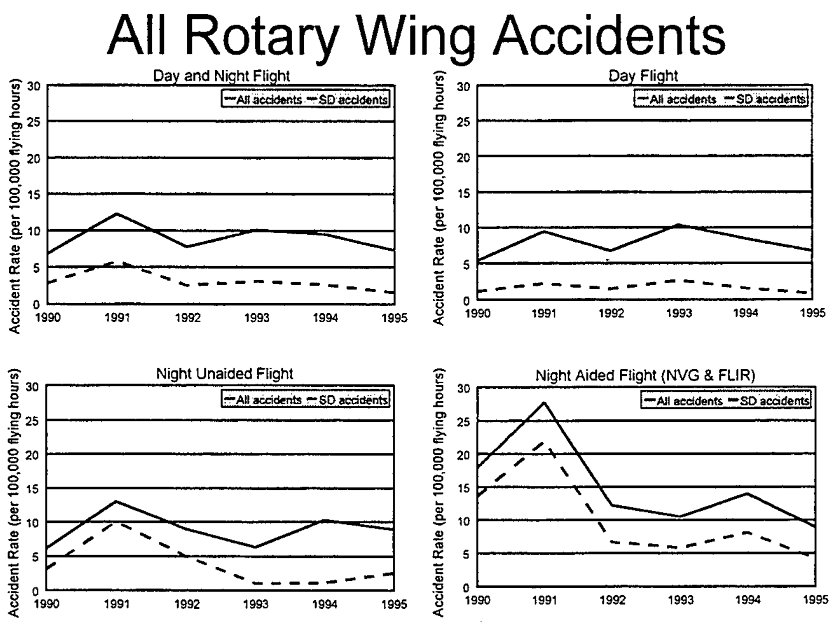


Figure 11. All rotary-wing accident rates.

Day and Night Flight

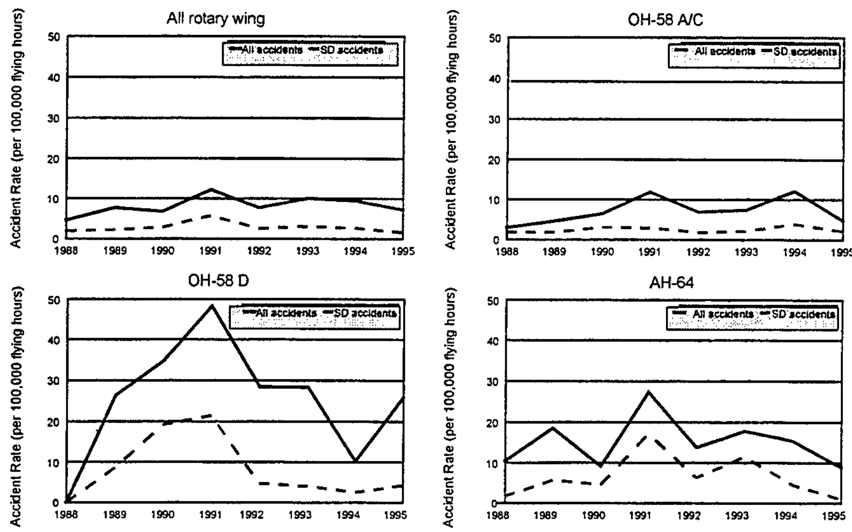


Figure 12. Day and night flight accident rates.

Height and speed

Accidents involving SD were associated with a significantly lower height above the ground at the onset of the emergency than were accidents in which SD did not occur. Figure 13 shows the average height at the center of each box and the variation represented by the box and whiskers. The results are not surprising, as the end point of incorrect or inappropriate control from SD is of course hitting the ground, and if one is near it to start with, the chances are greater. The high number of hover SD accidents is reflected in this statistic. Similarly, SD accidents occurred at a significantly lower airspeed (figure 14). This is again due to the many hover accidents.

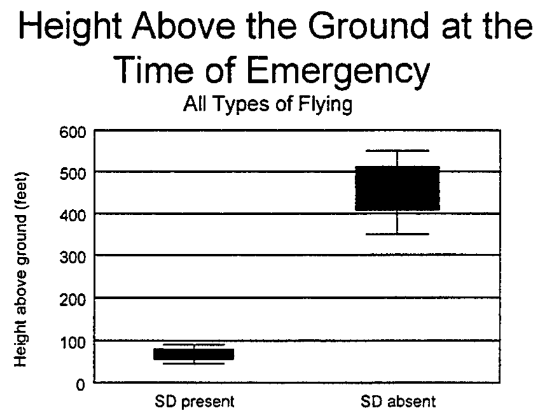


Figure 13. Height above the ground at the time of emergency.

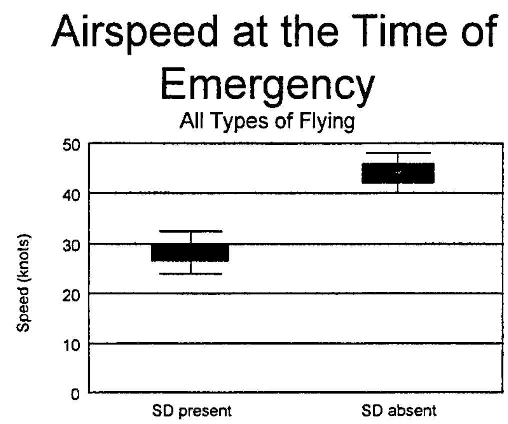


Figure 14. Airspeed at the time of emergency.

Number of crew disoriented

In 59 percent (178) of all SD accidents, both front seat crew members were affected by SD. This can be broken down into day and night figures as shown in figure 15. In an aircrew survey conducted in 1993 which asked about aviators' personal experience, it was much less frequent for both crew to have lost orientation. The fact that there was an accident of course implies that the other crew member was not "oriented" enough to prevent the disorientation of the handling pilot leading to loss of control.

Both crew were disoriented in:

- 59% of all SD accidents
- 70% of Night SD accidents
- 49% of Day SD accidents

[Aircrew survey: 2 crew disoriented in 29% of SD episodes]

Figure 15. Both crew disoriented.

Distraction

There was judged to be a distraction inside the cockpit in 26 percent of SD accidents and outside the cockpit in 29 percent. In some accidents, there were distractions both inside and outside. Distractions inside were predominant in OH-58 A/C and D models and AH-64, particularly during night aided flight, and distractions from outside were predominant in UH-1 and UH-60 accidents again during night aided flight. These findings are probably mission - related. This is obviously a most important feature in the sequence leading to the SD accident, and one which can probably be alleviated by vigorous crew coordination training. We are looking further at the type of distraction from the flying task.

Events

Although the Safety Center provides good data on some of the effects of the disorienting episode, we found it more useful to use a modified event classification when specifically considering SD. Although all aircraft ended up on the ground or in the water, the first category in figure 16 represents both controlled flight into terrain (CFIT) and inadvertent ground (or water) contact in translational flight. The second largest group, drift and/or descent in the hover is peculiar to vertical landing and take-off aircraft. Our study has emphasized the importance of SD in this phase of flight. We considered that most hover accidents were due to movement of the helicopter at a rate certainly below the threshold of the vestibular apparatus, and in many cases, below that of the visual system. Recirculation events (brownout and whiteout) accounted for some 18 percent of all accidents. If one asks aircrew "in what conditions are you most likely to get SD ?," the majority will answer instrument meteorological conditions (IMC). There is no doubt that there are probably more SD episodes in IMC, but our results show that there are very few accidents as a result. This is probably because aircrew expect SD in IMC and so are ready to counteract it, and also that events generally occur well away from the ground, so there is more time to recover. The small percentage of SD accidents associated with flight over water probably reflects the service role. The hazard is certainly there.

Disorientation is possible in good sight of the ground, or even on the ground. In taxi and hover-taxi accidents, perception of the gravitational vertical and horizon are generally good, but judgment of clearance from obstacles has been poor or not attended to in some cases.

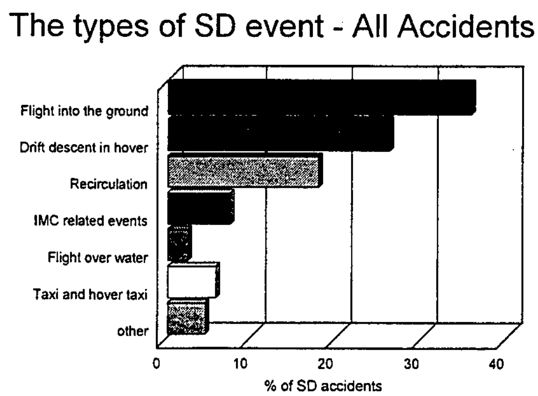


Figure 16. The types of SD event - all accidents.

The graph for day accidents is similar in its relative proportions to that for all accidents and is not reproduced here, but there are some subtle differences in night flight. In unaided night flight (figure 17), the top two categories again predominate. The proportion of IMC-related events, however, has not surprisingly gone up. Unaided night flight is generally conducted closer to the weather.

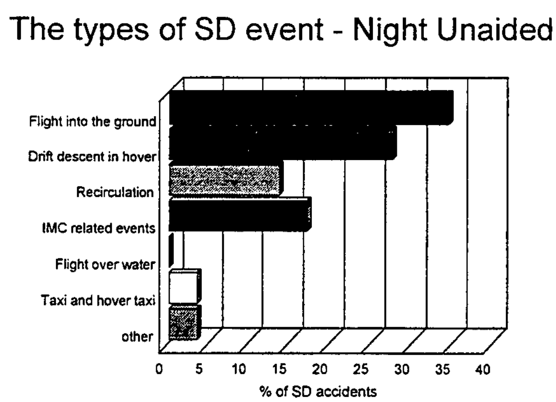


Figure 17. The types of SD event - night unaided.

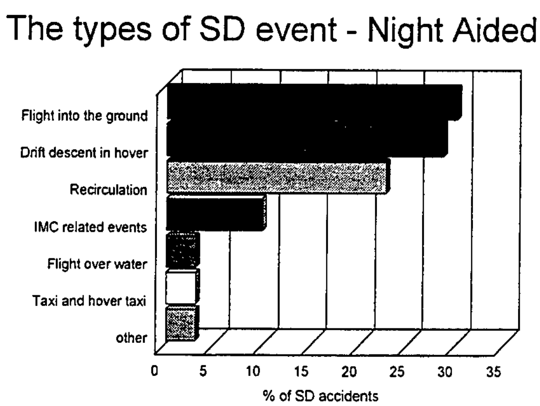


Figure 18. The types of SD events - night aided.

Factors leading to the mishap

We can examine what went wrong to cause the accident in several ways. For instance, did the handling pilot misjudge a flight parameter? Figure 19 shows that misjudgment of clearance from an obstacle is overwhelming in its prevalence, with most of the instances occurring in the hover. Similarly, misjudgment of altitude was more frequent because of the hover accidents where there was less room for error.

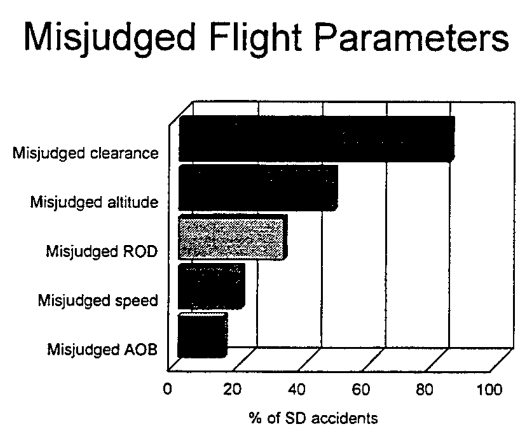


Figure 19. Misjudged flight parameters.

Some other important features are shown in figure 20. Brownout alone accounted for almost 15 percent of the SD accidents. Illusions from remote sensors are peculiar to the AH-64 in the current fleet of Army helicopters. There were only four cases, but this will continue to be a potential problem whenever we look at an image that is not generated very close to the eye.

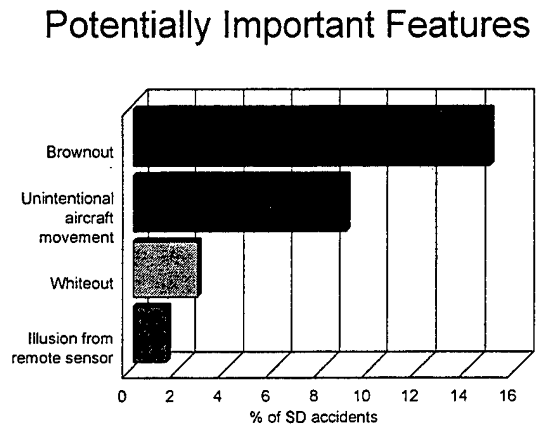


Figure 20. Potentially important features.

Next, we tried to evaluate the perceptual difficulties arising in the accident sequence. It can be seen in figure 21 that very few illusions caused SD accidents, whereas a deficiency of visual cues (i.e., absence of the primary aid to orientation) were featured in almost 25 percent. An interesting comparison can be made here between SD accidents and incidents. Figure 22 shows these features in the percentage of accidents compared to the percentage of SD episodes gathered from the 1993 survey of aircrew. It can be seen that while there were still a lot of cases of insufficient visual cues in both series, misleading visual and vestibular cues (the illusions) were much more frequent in SD episodes that didn't lead to accidents. In other words, these instances of type 2 SD are recognized by aircrew and are generally overcome.

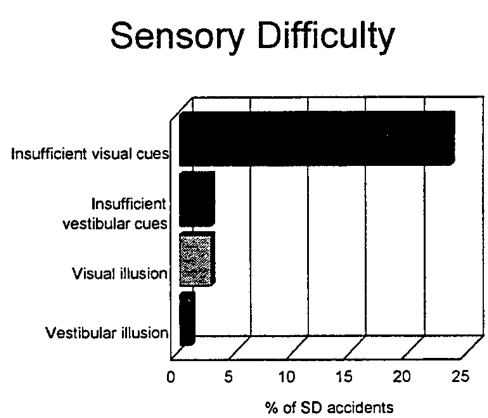


Figure 21. Sensory difficulty (1).

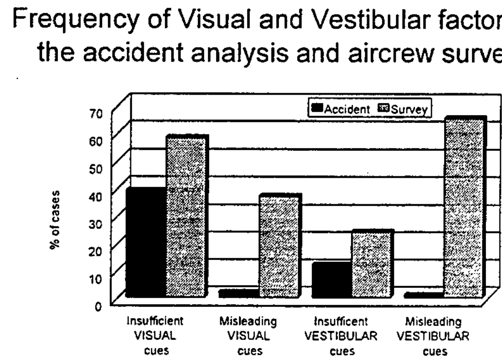


Figure 22. Frequency of visual and vestibular factors in the accident analysis and aircrew survey.

Because of the high proportion of SD accidents using NVDs, we have started to try to evaluate the problem. Figure 23 illustrates the fact that visual limitations associated with these devices, particularly the restricted field of view, were considered to contribute to almost 30 percent of the SD accidents. The middle two categories in figure 23 both relate to AH-64 FLIR flying. Although the information to assist orientation is presented in the integrated helmet and display sighting systems (IHADSS), it is not necessarily interpreted correctly or may even be ignored.

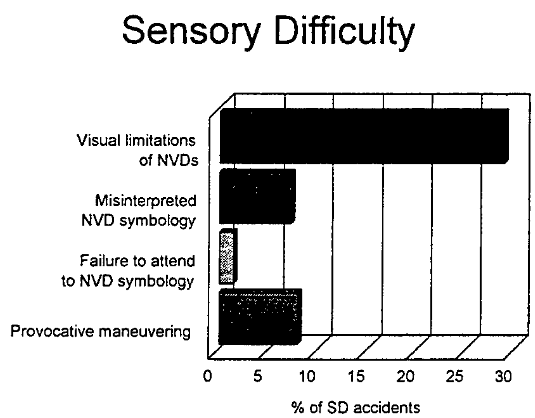


Figure 23. Sensory difficulty (2).

Combat training losses

The increased risk of SD during the Gulf War could probably have been anticipated. Fifty percent of the total helicopter losses in Saudi Arabia were considered to have involved SD as the major factor. When these data were compared to those from other desert locations, there was a significantly greater proportion of SD accidents from the Gulf, so terrain is unlikely to be the factor. As in previous studies, there seems to be a "wartime effect" on SD - the increased pressures of war or perhaps reduced safety margins. "Owning the night" does not come without

risks; 81 percent of Saudi nighttime losses were due to SD. It must be remembered that the operational costs of SD are not limited to aircraft losses since few episodes of SD actually lead to accidents. A high SD accident rate, therefore, implies an extra loss of operational efficiency due to SD incidents of varying severity.

Predisposing factors

As in previous surveys, aircrew experience, as measured by their total flying hours or years spent flying, does not confer immunity to SD. It is reassuring that neither hours of work nor hours of sleep prior to the accident appeared to be related to SD accident rates, but there should be no complacency in monitoring these areas. The absence of a link with "currency" (as defined by flying hours in the previous 30 days) suggests that either the accident numbers involved are too small to be sensitive to slight variations in currency, or maybe aircrew with less "currency" give themselves greater margins for safety.

Mishap coding issues

Only 32 accidents had been coded as SD by the Safety Center. These were mostly the brownout, whiteout and some IMC-related mishaps. We agreed with these codings, but considered that at least an additional 44 accidents should have had the Disorientation Safety Center code. Of course, we classified a further 214 accidents as having SD as the major or contributory factor. In these accidents, we applied one of the other two Safety Center "SD related" categories, Scan and Estimate, as shown in figure 24. Many of the SD accidents, therefore, may well be hidden in other Safety Center categories. This disparity in classification is due in part to semantics. SD means different things to different groups of people and the gray area that surrounds all human factor accidents adds to the problem. Similarly, if boards of inquiry have not been primed to watch for SD, they may not consider it, or may classify accidents to related factors such as lack of crew coordination.

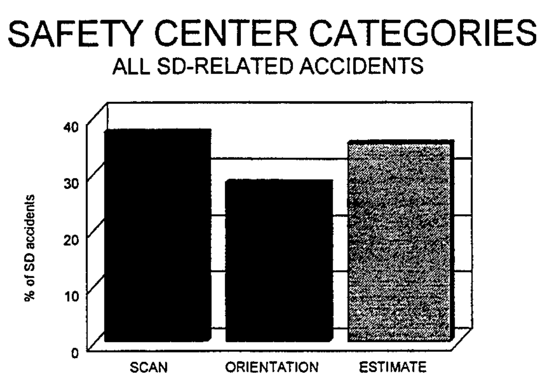


Figure 24. Safety Center categories.

The nature of rotary-wing SD

This study confirms the wide ranging nature of SD in U.S. Army helicopter operations. While the well known causes do exist, they do not appear to predominate. For example, "brownout," "whiteout," or "inadvertent entry to IMC" among them account for only 25 percent of the SD accidents. Other "textbook" conditions such as flicker vertigo or illusions due to downwash proved almost non-existent in our accident database, although they were reported in the aircrew survey. Similarly, there were no obvious cases of vestibular illusions causing accidents, although we cannot rule out low grade vestibular disturbances. Aircrew distraction was thought to play a part in 44 percent of SD accidents. The role of poor visual cues was highlighted by the relationship between SD and night flight, and by the high percentage of accidents in which the inadequacies of NVDs were considered to have played a part. There is possibly a poor awareness among aircrew of how to prevent and overcome SD, but this is conjecture until the hypothesis is properly tested.

From the findings of this accident analysis, it can be concluded that the "typical" picture of rotary-wing SD is less one of a classical vestibular or visual illusion giving a pilot vertigo, but more one of hard-pressed aircrew flying a systems intensive aircraft using NVDs failing to detect a dangerous flight path. This matches with the high proportion of SD type 1 accidents that are present, as classical SD episodes such as inadvertent entry to IMC or recirculation problems are more likely to be type 2.

Potential solutions

The flight surgeons who reviewed the accidents were asked to check a list of potential solutions for their applicability to the accident in question, as well as offering alternative recommendations. Figure 25 illustrates the findings. It was salutary to find that the potential solution most often cited was nothing to do with technical hardware, but was simply "improved crew coordination." Indeed many of the recommendations from the accident reports suggested that the training in this area that has now been started should be enhanced. In many accidents, better allocation of crew duties, for example, one pilot with his head "inside" and one with his head "outside" the cockpit, might have meant that at least one crew member would have escaped disorientation. Allied to better crew coordination was another frequently identified potential solution, "improved scanning." As far as hardware solutions are concerned, the most immediately beneficial would be the introduction of an audio warning on the radar altimeter. This is lacking in many aircraft, despite the fact that the technology is "on the shelf" and cheap. Given the situational awareness demands on modern aircrew, can we afford not to have this simple and highly beneficial device? Hover-locks would enable aircrew to hold a hover with a lower workload, and drift indicators could provide important information about station-keeping. Another potential solution of particular importance to night flyers is injected symbology for NVGs, the NVG head-up display (HUD). However, as mentioned earlier, providing symbology

does not necessarily mean that aircrew will pay attention to it. Peripheral vision devices and other improvements in general instrumentation do not appear likely to be of great benefit.

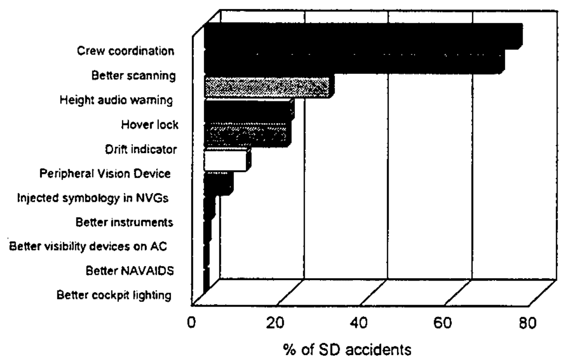


Figure 25. Potential solutions.

Conclusion

The following points are made in conclusion:

- SD is an important source of attrition of Army helicopter operations, costing an average $58 million dollars and 14 lives each year.

- SD accidents increased significantly during the Gulf War. Similar findings from other war zones (for example, the Falklands) suggest that combat may lead to lowered safety margins. The fact that 81 percent of nighttime accident losses in Saudi Arabia could be attributed to SD highlights the grave military implications of this problem.

- The contribution of SD accidents to the overall accident rate is not getting smaller. The increase in risk associated with night vision devices when compared to day flying is of particular concern.

- The conditions which predispose to type 2 SD, such as brownout or inadvertent entry to IMC, are likely to be well known to aircrew and thus more readily overcome. The helicopter SD accident is not one of classical vestibular or visual illusions giving a pilot "vertigo," but is one of loss of orientational cues leading to contact with the ground or an obstacle.

- The fact that better crew coordination or scanning might have prevented many accidents suggests that aircrew are less likely to be aware of the risk of distraction and the limitations of their orientational senses which lead to type 1 SD. This aspect is open to training.

Recommendations

Recommendations are subdivided into training and technological issues in figures 26 and 27, respectively. They are discussed further in the paper, "SD - Initiatives to overcome a significant impact on rotary-wing operations" later in these proceedings.

RECOMMENDATIONS - Training

- Commanders to be made aware of the potential threat that SD poses during peace and war.
- Detailed refresher training on the causes, manifestations and effects of SD.
- Explore the use of standard aircraft simulators for SD training.
- Intensify aircrew training in crew coordination and scanning.

Figure 26. Recommendations - training.

RECOMMENDATIONS - Technology

- Fit audio warnings on radar altimeters.
- Pursue the introduction of the NVG 'HUD'.
- Continue the development of 'hover locks' and similar devices to reduce workload.
- Develop a helicopter specific instrument panel (including the provision of hover and drift information).

Continue research into the specific causes of military RW SD and potential solutions.

Figure 27. Recommendations - technology.

Impact of SD on U.S. Navy rotary-wing operations

Captain Myron Almond's presentation is not recorded in these proceedings as it contained sensitive material.

Impact of SD on U.S. Marine Corps (USMC) rotary-wing operations

Commander Rick Mason gave the following presentation. The verbal text is supported by figures 28 to 34.

IMPACT OF SD ON USMC ROTARY WING OPERATIONS

CDR RICK MASON
3D MARINE AIRCRAFT WING
DSN: 997-4013

"You never get a second chance to make a first impression." Head & Shoulders commercial

Figure 28. Title - CDR Rick Mason.

Introduction

The USMC has approximately 550 helicopters of the type designed to support the guy on the ground. The breakdown is shown in figure 29. The CH-46 is a troop transport, equivalent to the UH-60. The CH-53 D/E have a heavy lift capability and are equivalent to the CH-47E. The UH-1N are used in the same role as the Army uses Kiowas, Hueys, UH-60s and Cobras. The attack helicopter in the USMC is the AH-1W.

ORGANIZATION

- APPROX 530 HELOS
  - 172 - CH-46E
  - 140 - CH-53D/E
  - 80 - UH-1N
  - 140 - AH-1W
- 5 HELO MAGS: 2 PAC, 2 LANT, 1 WESTPAC
- FOUNDATION IS THE ACE OF THE MEU (COMPOSITE SQDN OF 12 CH-46, 4 CH-53, 4 AH-1W, 3 UH-1N, AND 6 AV-8B)

Figure 29. Organization.

The USMC is organized into squadrons and Marine aircraft groups that can range from 4-10 squadrons within a group. The groups are primarily organized upon aircraft type which will become mixed whenever they go operational. The nucleus of the Marine aviation helicopter force is a Marine Expeditionary Unit (MEU) and its aviation combat element consists of a nucleus of an H-46 squadron with attachments of CH-53s, Cobras, and Hueys. They are designed to support a battalion landing team. The intensity of operations is shown in figure 30.

INTENSITY OF OPERATIONS

AT ANY GIVEN TIME:

- 2 MEUS ARE FLOATING (MED/SWA/PAC)
- 2 ARE IN WORK-UPS
- 1 IS EITHER FLOATING OR IN WORK-UPS
- APPROX 20% ARE OPERATING AWAY FROM HOME BASE

"Don't mind the mules, just load the wagons." Unknown

Figure 30. Intensity of operations.

Mishap rates

The mishap rates are shown in figure 31. Note the total for the 1990s so far: 4.01 for USMC aviation, with a rotary-wing rate of 3.52. We have a relatively high accident rate, but it must be remembered that most flights are operational. We are heavily tasked for deployment and don't have any kind of training command.

CLASS A FLIGHT MISHAP RATES

	USMC RATE/#	RW RATE/#	SD(?) INVOLVED
FY90	6.28/26	3.31/6	3/6
FY91	4.47/20	5.32/10	6/10
FY92	4.02/16	4.26/7	3/7
FY93	4.41/17	5.98/10	4/10
FY94	2.08/8	1.17/2	1/2
FY95	3.02/12	2.06/4	1/4
FY96	3.78/14	1.12/4	0/4
Totals	4.01/113	3.52/43	18/43 (42%)

"Statistics are no substitute for judgement." Henry Clay

Figure 31. Class A flight mishap rates.

When I was requested to give this brief, I called up the Safety Center and got all the numbers from them. What was interesting was that the numbers of SD mishaps was extremely low. Fortunately, I had access to our files for FY 94-96 and I started comparing what I had as far as the actual mishaps and the write ups that the Safety Center was quoting as "an SD mishap." The numbers didn't agree. It was a coding issue as far as what they determined to be "an SD mishap." So, the number on figure 31, 18 out of 43 mishaps (or 42 percent of the rotary-wing mishaps) is not Safety Center data. It's only when you start breaking down each individual mishap that you start getting some SD factors. I should comment that one reason I have "SD?" in the column heading is because it depends on the definition of SD. Some of these may be more "loss of situational awareness." Of these 18 mishaps that I classified as SD, 15 occurred away from the home operating airfield or base of either the aircrew or the aircraft. So, about 80 percent are occurring away from where these guys are normally operating.

As far as Class Bs, Class Cs, and incidents are concerned, I only had one or two come back from the Safety Center. I think again that's just a coding problem, so I don't have any data. If you really want some good first-hand accounts and "I've been there" stories, read the Safety Center magazine, "Approach." It's amazing what we get people to write and tell about themselves, and it's probably some of the best information as far as examples of people getting themselves in trouble. Fortunately, they're here to write about them, so I guess that's their bonus.

The typical SD mishap

See figure 32. Many of these factors have been addressed by previous speakers.

"TYPICAL" SD MISHAP

- FLIGHT NOT IN NORMAL OPERATING AREA
- DECREASED/ATYPICAL VISUAL CUES
- CREW NOT MONITORING FLIGHT PATH
- RESULTS IN CFIT

"Few things are harder to put with than a good example."
Mark Twain

Figure 32. "Typical" SD mishap.

We've worked on a concept called the "spatial orientation equation" (figure 33). Since this is primarily an Army audience, I figured I would say it was operational risk management for SD. We have three primary factors: a distraction, over a given length of time, and in a certain environment. What we basically say is that if you start adding up (and I won't put any numbers to it), it doesn't take much of a distraction for a very long period of time before that person gets them self into a high potential for a disorientation. We don't see people getting spatially disoriented flying at 3,000 feet day VFR, just monitoring the airways and the radios. But if you put them close to the ground in a tactical situation in marginal weather on night vision devices, and they've got people chattering at them, it doesn't take much before they're task overloaded and not really keeping track of what their instruments are telling them.

SD EQUATION (SD ORM?)

SD = [Distraction x Time] Environment

EP	Night
Comm	Wx
Task Saturation	NVDs
Scan Regression	TERF
Aeromedical	Formation
Aircrew Coord	Tactical

Figure 33. SD equation (SD ORM?)

Command concern

IS HQMC CONCERNED?

- AVIATION SAFETY? YES
- SD MISHAPS? NO
- AVIATION SAFETY CAMPAIGN PLAN
- INCREASED EMPHASIS ON SIMULATORS

"The more you practice what you know, the more you know what you practice." Dan McKinnon

Figure 34. Is HQMC concerned?

See figure 34. Headquarters USMC is concerned about aviation safety. In fact, as of 1 Sep 96, there is something called the aviation safety campaign plan that USMC aviation has undertaken primarily based upon the high mishap rate. They are trying to solve some of the problems, but most have nothing to do with things that would pertain to this discussion on SD. Most of them are things like maintenance, manning and actual loading of squadrons with training events, etc. One thing that is a big issue and has something to do with this audience is that the USMC is going to put an increased emphasis on simulators. I'll talk more of the way the USMC trains their pilots in the session on training, but essentially the plan is not to add simulator events unless you can pull out an actual flight evolution. They want to try and save some aircraft wear and tear and also try to reduce the risk. Right now it is planned that an initial Osprey pilot will have approximately 80 percent of his time becoming qualified spent in a simulator. He is only going to have 20 percent of his time spent in the actual aircraft.

Is there concern about SD mishaps? No. Why? Because people like me haven't made enough of an issue of it and I think that after this meeting, it may be elevated to a higher level. But as far as pinpointing the area is concerned, it's not happening. A lot of issues that are in the aviation safety campaign plan will address these issues right here, but no one has said formally at the HQMC, "go after the SD mishap rate and try to solve it."

Impact of SD on U.S. Air Force (USAF) rotary-wing operations

Lieutenant Colonel Jeffrey Hill's contribution to this presentation contained sensitive material and is not recorded in these proceedings.

Lieutenant Colonel Jay Johnson gave the following presentation.

I am honored to address this conference. I can talk to you about SD from a pilot's and safety staff officer's point of view.

The USAF doesn't appear to classify mishaps as simply SD mishaps. The USAF safety boards tend to break the causes down into smaller divisions such as "didn't judge the closure rate" or "inadvertently entered weather and departed controlled flight." In order to find SD in our mishaps, you have to ask the data base very specific questions and even then you may or may not find all of the data you're looking for. I was only able to find three mishaps where SD was mentioned as just "SD." I found five others when I queried the data base for brown and whiteouts. Only one of these was a Class A, B, or C mishap, the others being high accident potential (HAP) reports.

The USAF does not own a large fleet of helicopters. Our helicopters consist of MH-53's, MH/HH-60's and UH-1N's. They are split among various commands, tasked with quite different missions including: combat rescue, special operations, VIP support, nuclear site support, and operational testing. We don't have a lot of helicopters, but we have the same mishap problems as all of the services.

The operations tempo is quite high. It's nice to know you're needed, but it would also be nice to be manned for the demand. Our deployment rate at any one point in time is about 35 percent of the total fleet. The H-53 had a mishap rate of 7.88 per 100,000 hours last year, but this was only 1 Class A over the 21,000 flying hours the H-53 flew. The small number of flying hours contribute to a higher rate. We don't have much of a Class B rate, either. We either ding them or destroy them.

So far in 1996 there have been zero SD incidents. From 1985 through 1995, the data base shows SD to be a cause in 8 mishaps, but only one of the mishaps was a Class A mishap (no fatalities). It was a classic SD mishap. The crew flew an NVG approach, entered a brownout and the copilot called for a go-around. The aircraft commander then said "let's do it again." This time when the helicopter entered the brownout, no one called for anything before the aircraft commander became disoriented and rolled the aircraft. The other seven incidents were HAP reports which should be considered just as important because they were Class As separated by time, distance, and luck.

So far, the data indicates that SD is not a problem. I dispute that. Just because we've not crashed more aircraft is not a reason to disregard SD's importance. We need to do a better job of

classifying SD, inputting it into the data base, and then analyzing the data to inform crews of the highest possibilities for suffering SD and putting themselves into a position of creating a mishap.

Discussion session

The discussion at this session was transcribed from audio tape. Questions are prefixed by "Q," answers by "A," and interjected statements by "S."

Q - CPT Kevin McMullen. Numbers of Army aviation incidents that glitch around Desert Shield/Storm. The hard part I have in the discussion of that is my commander has a dictum where he says "mission first in combat, safety first in training." And obviously there was a different situation going on at that time. I know there were some concerns, so how was that area in time handled in terms of the way the Army looks at SD?

A - Lt Col Braithwaite. Those were not combat losses, they were accidents that occurred in training (in theater). Everything we documented were accidents. By definition, combat losses are excluded from our definition of accidents.

S - Mr. Mike Moran. Let me offer historical perspective to the collection of this data. We started looking at data in the early 1980's because the Army has such a large rotary-wing fleet. One of the first things we noticed was that even if you did a word search in the Safety Center under SD, or vertigo, several things popped up right away. Number one, it always happened in a Class A accident. Number two, it usually involved a fatality. The second thing that we had to be very careful of was to be very conservative in our collection of data. So the data that you've seen today as far as the Army is concerned is very conservative data. There's a very good reason for this. The guys that are looking at this are probably the only ones in the Army that are trained to look for SD. The guys that are in the field actually collecting the data for the mishap investigation have not been trained. Nor is it on their checklist to look for SD. So when you take after-the-fact data and you're trying to second guess what happened in that accident, you have to err on the side of caution. I just offer that as historical perspective, that the data put out by the Safety Center today is very conservative data. When we did an initial scrub right after Desert Shield/Storm, the Class A accidents (not birds that got shot down or the ones going out on a combat mission). We're talking about training ash/trash missions that hit sand dunes, that from brown/whiteout conditions, 75-80 percent of these accidents in which a fatality occurred were initially looked at as SD. We had to say, "Wait, maybe we need to go back and take a look at these things and really scrub them carefully." Because it is a serious area that we have been unable to get our arms around in terms of training it out of existence. We're not doing a good job of training it. The instrumentation that's in our birds traditionally, historically, have come from fixed wing aircraft. So you've got fixed wing instrumentation in a rotary-wing aircraft that we're trying to adapt to do new missions that quite frankly didn't exist 20 years ago in Vietnam. We didn't do masking and unmasking at 1 o'clock in the morning with night vision goggles, with HELLFIRE missiles strapped to the side of UH-1s. But that's what we're asking Apache pilots to do today. And when he gets into a drift situation that's less than 1 or 2 feet per second,

he physiologically can't detect it. It's outside his envelope. Is that SD? Yes, it's part of that awareness issue.

Q - MAJ Keith Steinhurst. Question for USAF - I thought I heard you say that you had one SD mishap? Since visual cues are a large part of that and since I know you all have a special procedure you use when you goggle up, I wanted to ask you about the data between the test lane goggling vs. not using the test lanes, and what information you can give us about numbers on that.

A - Lt Col Neubauer. When the test lane is used properly, we don't have the problems in the hover and over the water that we've had in the past, but for about 4-5 years we just couldn't get the people to walk in the room, get in the lanes, sight the goggles correctly and then go out to the airplane. What we found out was that people were going out to the airplane and looking at the lights on the runway, focusing the goggles and then going to fly. Between 15-30 minutes of flight, you can see the guys raising the goggles up and rubbing their eyes. When we'd bring them back in and get the doctors involved and then the people would correctly sight the goggles in the lane, they'd go out and they could fly for about 2 hours before they ended up flipping their goggles up and rubbing their eyes. You can only put the lane there and post the procedures and tell the people to do it, and if they don't do it, then you end up with problems. It's in the regulations, it has to be done before every flight, the aircraft commander's responsible for making sure everybody does it. Whether they do it or not 100 percent of the time, I couldn't tell you, but I doubt it.

Q - Mr. Bob Brooks. Question for the Army. When you talked about visual limitations, specifically field of view (FOV) leading to 30 percent of the SD accidents, how did you come up with that number?

A - Lt Col Braithwaite. This was part of the analysis of the SD accidents that we undertook with the three flight surgeons asking them specifically did they feel there were any limitations with the NVDs that were responsible for contributing to SD in that accident?

Q - Mr. Bob Brooks. Was that specifically when it was written in the red book? Or was this just speculation on the folks who evaluated the red books?

A - Lt Col Braithwaite. I wouldn't call it speculation, I'd call it interpretation. Based upon what was written and what was implied.

Q - Mr. Bob Brooks. You talk about how crew coordination could and should be enhanced. Are you just talking about that, or is there any document going forward recommending that to anybody?

A - Lt Col Braithwaite. There has been no document as a result of my updated series of accidents, but it was one of the recommendations from my predecessor's report which has been

published as a USAARL report and been circulated far and wide within the Army community, not least to the Safety Center. I reiterate the point that there were many recommendations from the accident reports themselves that said that we should really get to grips with the crew coordination training which we've now started, make sure that everybody completes the training, and in many cases, consider refresher training as well.

Q - CW4 Smolka. A question for the Navy on your accident data. You said it's exclusive to all trainers or training aircraft. How would it affect the accident rate if you were to include all of the operational accidents and training accidents into the same rates?

A - Capt Almond. That's a good question. In fact, Lt Cdr Smith, our psychologist, is looking at that factor by putting the training aircraft into the human factors analysis database. This will be briefed to the Navy Air Board, and that's one of the questions they ask, also. It's so current and new that they haven't done it yet, but that's the next step.

Q - CW4 Smolka. For Cdr Mason - You referenced a training manual that you used for USMC operations. Is it available to other services?

A - Cdr Mason. It's not really a training manual, per se, but a matrix for what they consider to be a combat capable pilot. Yes, it is available. Going back to what you asked, Captain Almond, I know that if you were to include the training mishaps on the helicopter side, it would drive the numbers down significantly because we haven't had a Class A helicopter mishap in (I think) 18 years.

Q - Mr. Bill Ercoline. I think I understood you to say that there are very few vestibular SD mishaps from the rotary-wing aspect. It seems in that environment, that would probably be one of the biggest problems you would have, so either you're doing something correct in training, or something. Because even when we go out in the Barany Chair, when you put your head down to the side and rotate just a bit, as soon as you pull your head up, you're going to get a strong sensation to probably push the nose down, or something like that. So, how would you explain this lack of vestibular effects?

A - Lt Col Braithwaite. What I'm trying to emphasize is that the classical vestibular illusions that we read about in our text books and most of us are trained upon as the causes of SD: the somatogravic illusion, coriolis, and so on, which are the obvious illusions, do not appear to be prevalent in the accident database. There are vestibular disturbances, I am quite sure, but most of them are sub-threshold ones. Ones we don't perceive. The emphasis is to try and redress the balance from a position that you're not going to feel that you're going to be spatially disorientated in the way that you do on the Barany chair where you feel dizzy, but that rotary-wing SD is more likely to have an insidious onset because your vestibular system may well be being stimulated, but at a rate below what you can perceive.

Q - Dr. Tamara Chelette. G-excess illusion: A lot of times I saw in the taxonomies: "major cause, failure to notice decent into water." You could easily phrase that differently to say "potentially, pilot experienced G-excess illusion that created decent into water." So, some of these comments are a question of taxonomy. The taxonomy does not include a lot of words that are vestibular illusions.

A - Lt Col Braithwaite. That's a perfectly valid point. To bring up a question you asked earlier this morning. There may be somebody here now that can answer it. Do we train aviators on G-excess illusion? I cannot recall seeing that in the FM-301.

A - CPT Thompson. No, we do not teach that.

S - Dr. Chelette. I would like to send you a video tape that the USAF produced about 4 years ago as a training tape to go out to pilots. It does an excellent job of explaining how that illusion can occur and what could result.

Q - CW4 Antoskow. One of the recommendations you had was an audio warning on the radar altimeter. This gives you straight down capability, and some of the accidents you showed occurred over sloping terrain, that's not going to help you in that situation. Over water, sure. I've flown a lot of goggles and invariably, a radar altimeter would not have helped me on some of the close calls that I've had where I need proximity warning on something out there. That technology is out there.

A - Lt Col Braithwaite. You're right. We only made the recommendation where it would have helped, in those accidents where the aircraft impacted vertically.

S - CW5 Bill Ramsey. I was the standardization officer for the 1-17th Cav which had the first of the OH-58 accidents in Desert Storm. The instructor pilot (IP) had 7,000 hours flight time. We thought we were well qualified to handle the situation in the desert, due to National Training Center (NTC). Come to find out, the first accident, he flew the aircraft into the ground, into a sand dune. Slow decent, thought he was under control, was not. We went back and looked at the accident and discussed it with the board. Figured we needed to do some daytime training to instill in our pilots that the situation was different. We came to find out that we were dealing with more than one visual illusion at a time. We could have a combination of visual illusions. I think that was what was confusing the pilots. They were able to recognize one, but when it came to three or four, they had a problem with it. We went out and did daytime training, had talks, pulled out manuals, and talked about visual illusions. We sent out a team to train, they trained daytime and night. Good crew coordination. We sat down every week with all the pilots and discussed visual illusions to prevent us driving planes into the sand. It wasn't just one illusion. It was a combination. We talked about the OH-58D Task Force 118 that had the software in their system that could give them an audio and visual indication once you descended below 50 feet. It took us two accidents before 1-17th Cav got the software to be put in that airplane so we'd have some assistance. Not only did it keep us from running into the sand dunes in front of

us, but it did give us a safe margin of things below us. Pilots scream and holler to give us things that will help protect us. *Wings* was talking about a 1-17 that crashed a couple of years ago in the desert. They said pilots had a problem with illusions and getting SD. They put a system in that airplane that the guy got in trouble for. It would right that airplane back up. Is that true?

S - Lt Col Neubauer. There has been some work with the ground avoidance system. Initially, the ground avoidance system had some problems with acceptance among the pilot community. Pilots are very reticent to give over control to something they have no control over. Therefore, it has been slow to be accepted within the USAF community.

Q - Unidentified. Who covers accident statistics for DEA and shallow water Navy Coast Guard?

A - Lt Col Braithwaite. Department of Public Transportation.

Q - Unidentified. Wouldn't they have a higher incidence of SD accidents?

A - Lt Col Braithwaite. There is no representative here, but I believe the Coast Guard's incidence of SD is actually quite low, primarily because they have a helicopter called the Dauphin, that will do it all for you. All their helicopters are equipped with an automatic hover hold system. They come into a hover, it just sits there and holds for them, they don't have to worry about hitting the water. They're limited on the altitudes they fly, and they don't do a tremendous amount of night training.

S - Lt Col Braithwaite. Thank you to the speakers. Are we all convinced in this forum that SD has a serious impact? All agreed. We are the professionals in aeromedical and safety environment. What we need to do, and as one of the objectives of this symposium is to be able to project our concern onto the people who can help us overcome this problem. Let's think about how we can move things forward now that we've been able to bring everybody together here and share our concern for SD in the rotary-wing environment. Please be thinking how we can push that concern onto our immediate commanders, up to your commanding officers/generals, so that we can come out with some action plans that we can implement later on.

Session 2: Training initiatives to overcome SD in rotary-wing operations

Introduction

We heard in Session 1 about the size of the SD problem. This session concerns what we, as aeromedical and safety professionals, can do about it. One of the generic aims of anyone with a responsibility for flight safety and operational effectiveness is to impart new found knowledge to the user, the aviator and his or her commander. Without an understanding of the nature and effects of SD, the aviator is poorly placed to deal with the problem when it will inevitably face him or her.

Training is, therefore, the first pre-requisite of the control of SD. Because it is relatively "low-tech," it does not attract the sort of attention that it deserves. We are here to redress that balance. Our aviator training requirements are, in fact, regulated by standard NATO agreements and other air standardization agreements. It's going to be interesting to hear whether we really comply with those requirements.

Training initiatives to overcome SD in the Army

Captain Greg Thompson started this presentation. Figures 35 to 42 are a self-explanatory outline of his presentation.

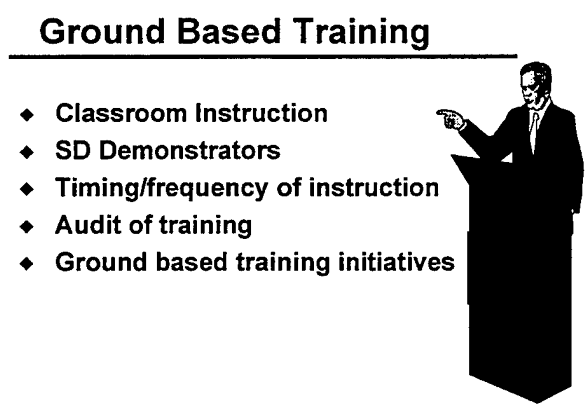


Figure 35. Ground based training.

Terminal Learning Objective:

While performing as an aircrew member, the student will manage SD in accordance with (IAW) FM 1-301 and FM 8-2

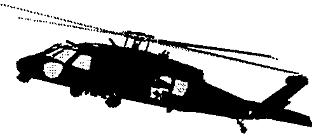


Figure 36. Terminal learning objective.

Enabling Learning Objectives:

- Identify correct SD terminology
- Identify the visual system
- Identify visual illusions
- Identify components of vestibular system
- Identify vestibular illusions
- Identify proprioceptive mechanism of equilibrium
- Identify classification of SD
- Identify measures of SD prevention
- Identify SD corrective actions

Figure 37. Enabling learning objectives.

Aviator Instruction

- SD presented as a killer
- Recognition - Compensation
- Instrument Proficiency
- Terminology
- STANAG Compliance
- AIR STDS Compliance

Figure 38. Aviator instruction.

SD Demonstrators

- **Barany Chair modified with cyclic**
  - » Coriolis Illusion
  - » Nystagmus
  - » Graveyard scenarios - cyclic displacement
- **Average initial entry RW Class:** ***30***
- **Students undergoing Barany:** ***3***

Figure 39. SD demonstrators.

Frequency of Instruction

POI	*frequency*	*duration*
Initial Entry RW	once	3 hours
Transitions	once	1 hour
Instructor Pilots	once	1 hour
Fixed Wing Flight Engineers	once	1 hour
Refresher	none	-

Figure 40. Frequency of instruction.

Audit of training

- **Initial entry RW Aeromedical Factors Examination**
- **other POI written exams**
- **lesson plans undergo annual review**

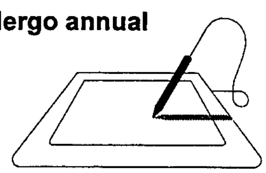


Figure 41. Audit of training.

Ground Based Training Initiatives

- **SD lesson plan in revision**
- **More time for SD demonstration**
- **Validate ground based training with airborne based demonstrations**
- **Inclusion of aircrew members (enlisted) to provide for crew coordination**
- **FM 1-301 in revision**

Figure 42. Ground based training initiatives.

Lieutenant Colonel Malcolm Braithwaite then presented the new initiative of the SD Demonstration Sortie. The text of his short presentation is given below. For a more comprehensive description of the SD Demonstration Sortie, readers are referred to a preprint of the author's submission to *Aviation, Space and Environmental Medicine* at appendix C.

We have a particular initiative in the Army aeromedical program to enhance the awareness of SD, the British Army Air Corps SD demonstration sortie.

It is well established that after lectures on SD, aircrew should experience some of the illusions in a ground based device. Most air forces also provide some instruction to their flight crew on how to cope with SD once it has occurred. Over 20 years ago, an AGARD working group recommended that an in-flight demonstration of SD should be given to all student aircrew. However, during some work I did on the standardization of some aspects of SD a couple of years ago, it was clear that very few services actually do this. We in British Army Aviation also suffer a great proportion of disorientation mishaps (currently about 16 percent of all helicopter accidents which cause two-thirds of the fatalities), and so we believe that there is a most important place for a demonstration to reinforce the fallibility of the orientation senses during an actual flying sortie.

The primary advantage of an airborne demonstration is that the student can experience his own limitations, and observe the reactions of his colleagues in the environment in which he is to operate (and not just in an odd-shaped piece of hardware on the ground). The demonstration is programmed towards the end of the basic rotary-wing phase of flight training, approximately four weeks after their aeromedical training module, and before the students commence rotary-wing instrument flight. Refresher sorties are flown every 4 years. All sorties are flown by Army flight surgeon pilots, and consist of a series of controlled maneuvers in both forward flight and hover. Three students are flown at a time, one being the blindfolded "subject" for a particular maneuver who gives a running commentary on his perception of the aircraft's motion. The other two students act as observers for a maneuver and then take their turn. The sortie is designed to

stress insidious disorientation - the start point of the sometimes catastrophic type 1 SD, and not to deliberately provoke classical vestibular illusions.

In the U.K., we have been flying this sortie for 14 years, and are able to demonstrate that since we have been conducting the sortie, the SD accident rate has been reduced from 2.04 accidents per 100,000 flying hours to 0.57. So, the sortie has saved lives and helicopters.

A further benefit is cost effectiveness. Most services employ some mechanical means to demonstrate SD. These devices tend to be expensive and we know of none that are tailored to the specific needs of the helicopter pilot. In 14 years, we have flown nearly 1700 students in 310 helicopter hours. Even using 1996 military operating costs, this represents a charge of about $150 per student. The total operating cost has been just over a quarter of a million dollars, or an average annual sum of $18,000. The overall figure is less than one tenth of the replacement cost of even the least expensive British Army helicopter, and it would take many years of training at this cost to justify the purchase of a modern SD simulator.

When I presented this topic at last year's Aerospace Medical Association (AsMA) meeting, I said that I believed that similar instruction could be readily adopted by other services and prove to be of great benefit. I am pleased to say that I am just about to start demonstrating the SD demonstration sortie to the U.S. Army. I have had to train an IP to actually fly the sortie, but it is most important that a flight surgeon is on-board to conduct the sortie and discuss the maneuvers.

I should also briefly mention training in the management of recognized (type 2) SD as opposed to demonstration of the limitations of the senses. This is learning flying procedures to cope with SD circumstances once they have been encountered, and is clearly the responsibility of the enlightened IP in both simulator and actual flying sorties. Most services seem to do this, but all too often, on an ad hoc basis. I firmly believe that recovery from unusual attitudes, and action upon inadvertent entry to IMC should be established as training objectives in the flight syllabus, and not merely be an occasional demonstration. Training should be aircraft type specific and, although some generic instruction may be possible on initial entry courses, further training will be required when a pilot first encounters different climatic or operational scenarios (for example, helicopter snow landings).

Training initiatives to overcome SD in the USAF

Squadron Leader Graeme Maidment started this presentation. Figures 43 to 56 are a self-explanatory outline of his presentation.

TRAINING INITIATIVES TO OVERCOME SD IN THE USAF

SQN LDR G MAIDMENT RAF

ARMSTRONG LABORATORY
SPATIAL DISORIENTATION
COUNTERMEASURES TASK GROUP

Figure 43. Title - Sqn Ldr G. Maidment, RAF.

ROTARY WING TRAINING IN THE USAF

- STUDENT COMMISSIONED
- SELECTED FOR FLYING TRAINING
- 20 HOURS ON T3
- SUPT - T34 OR T37 - GROUND-BASED SD TRAINING

Figure 44. Rotary-wing training in the USAF.

INITIAL GROUND-BASED SD TRAINING

- 3 DAYS AT APTF DURING SUPT
- CLASSROOM INSTRUCTION
- PRACTICAL DEMONSTRATIONS
  - BARANY CHAIR
  - VISTA VERTIGON

Figure 45. Initial ground based SD training.

INITIAL SD CLASSROOM INSTRUCTION

- TYPES OF DISORIENTATION
- VISION
  - FIELDS OF VISION
  - FOCAL AND AMBIENT VISION
  - DEPTH PERCEPTION
- VISUAL PERCEPTION ILLUSIONS
- LANDING ILLUSIONS
- NIGHT VISION AND NVGs

Figure 46. Initial SD classroom instruction.

INITIAL SD CLASSROOM INSTRUCTION (CONT)

- "INNER EAR" ILLUSIONS
  - LEANS
  - CORIOLIS ILLUSION
  - GIANT HAND ILLUSION
  - G-EXCESS EFFECT
- "SEAT-OF-THE-PANTS" PERCEPTION PROBLEMS
- RECOVERY FROM SD

Figure 47. Initial SD classroom instruction (cont).

**ROTARY WING TRAINING
AT FORT RUCKER**

- 6 WEEKS CONTACT FLYING
- 6 WEEKS INSTRUMENT TRAINING
  - UNUSUAL ATTITUDES
- 8 WEEKS BASIC COMBAT SKILLS
- 4 WEEKS NIGHT FLYING (INCLUDING NVGs)

Figure 48. Rotary-wing training at Fort Rucker.

**COMBAT CREW TRAINING AT
KIRTLAND AFB**

- TH-53A, MH-60G OR UH-1
- NO SPECIFIC IN-FLIGHT SD TRAINING
- NVG / INSTRUMENT FLYING AS PART OF SYLLABUS
- BROWNOUT / WHITEOUT
- EMPHASIS ON 'CRM' DURING DISORIENTATION

Figure 49. Combat crew training at Kirkland AFB.

REFRESHER TRAINING

- EVERY 3 YEARS
  - 1 DAY AT APTF
  - CLASSROOM INSTRUCTION
  - NO PRACTICAL DEMONSTRATIONS
- AIRC - ANNUAL INSTRUMENT REFRESHER COURSE
  - UNIT-LEVEL CLASSROOM TRAINING
  - INCLUDES SD
  - CONDUCTED BY GRADUATE OF AIS WITH ASDD EXPERIENCE

Figure 50. Refresher training.

STANDARDIZATION
DOCUMENTS

- STANAG 3114: AEROMEDICAL TRAINING OF FLIGHT CREW
- PROPOSED ADVISORY PUBLICATION 61/116/N:

  AVIATION MEDICINE / PHYSIOLOGICAL TRAINING OF AIRCREW IN SD

Figure 51. Standardization documents.

Mention should be made of the Gyrolab GL-2000 S. This is owned by the USAF School of Aviation Medicine (USAFSAM) as a disorientation demonstrator and trainer. Its full potential for research is still being explored. The device is able to move simultaneously in 4 axes (figure 52). The maximum rates of rotation and angular accelerations are shown in figure 53, and other features in figure 54. Motion can also be sub-threshold. Basic profiles (figure 55) have been written for fixed wing aircraft and evaluated in a successful troop trial. There was a 95 percent reliability for illusions (type 1) and sensory conflict (type 2). There is potential for more "advanced" profiles, with greater pilot interaction, and possibly for rotary-wing configured profiles. Possible examples are shown in figure 56. Forces could be produced to simulate transition to/from the hover, but might be limited by a lack of vertical translation. As yet, no customer has stated that they need this training in the rotary-wing community.

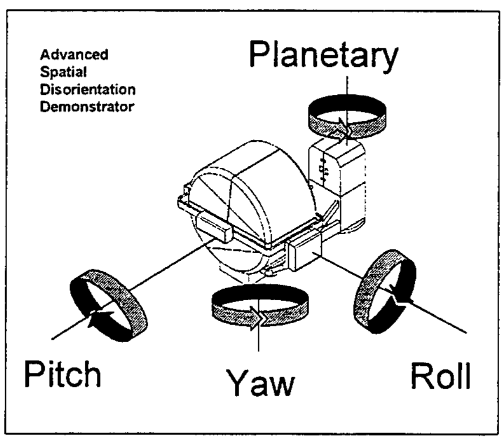


Figure 52. Advanced SD demonstrator (ASDD).

ASDD MOTION

MOTION	PLANETARY	PITCH	ROLL	YAW
MAX ACCEL DEG/SEC^2	15	50	100	30
MAX SPEED RPM (DEG/SEC)	28 (168)	8.3 (50)	10 (60)	25 (150)

Figure 53. ASDD motion.

FEATURES

- 360 DEGREES MOTION IN 4 AXES
- MAXIMUM 2.2G
- SEAMLESS WIDE FIELD OF VIEW VISUAL DISPLAY
- VARIABLE AIRCRAFT COCKPIT CONFIGURATION
- TRUE-READING INSTRUMENTS
- 'IN-THE-LOOP' CONTROL

Figure 54. ASDD features.

ASDD - BASIC PROFILES

- SUB-THRESHOLD MOVEMENT
- DARK TAKE-OFF (SOMATOGRAVIC ILLUSION)
  - PITCH
- GRAVEYARD SPIN (SOMATOGYRAL ILLUSION)
  - YAW
- GRAVEYARD SPIRAL
  - ROLL
- BLACK HOLE APPROACH (VISUAL ILLUSION)

Figure 55. ASDD basic profiles.

ASDD - POTENTIAL ROTARY-WING APPLICATIONS

- CONFIGURABLE COCKPIT
- TRANSITION TO / FROM HOVER
- HOVER
  - SUB-THRESHOLD MOVEMENT
  - YAW
  - COUNTER-ROTATION
- VISUALS - BROWNOUT / WHITEOUT
- NVGs

Figure 56. ASDD - Potential rotary-wing applications.

Lieutenant Colonel Jeffrey Hill then gave a presentation on USAF SD training as part of instrument refresher training. Figures 57 to 66 are a self-explanatory outline of his presentation.

Lt Col Jeffrey Hill

16 Operational Support Squadron

Hurlbert Fld, Florida

DSN 579-6242 jeff.hill@hurlburt.af.mil

2

Figure 57. Title - Lt Col Jeffrey Hill.

INSTRUMENT REFRESHER COURSE

- REQUIRED OF ALL USAF PILOTS
  - AFI 11-401
- AT LEAST EVERY 18 MONTHS
  - AFMAN 11-210
- SD IS REQUIRED TOPIC
  - IF POSSIBLE, BY PHYSIOLOGIST or FLIGHT SURGEON

3

Figure 58. Instrument refresher course (1).

INSTRUMENT REFRESHER COURSE

- RECOMMENDED OUTLINE
  - AFMAN 11-210
- NO STANDARDIZED PRESENTATION
- USUALLY ORGANIZED AS BASE LEVEL

4

Figure 59. Instrument refresher course (2).

INSTRUMENT REFRESHER COURSE
(AIR COMBAT COMMAND)

- DESIGNED FOR FIGHTERS
- ADDRESSES
  - HUMAN PERCEPTION
  - SD
  - SITUATIONAL AWARENESS

5

Figure 60. Instrument refresher course (Air Combat Command) (1).

INSTRUMENT REFRESHER COURSE
OBJECTIVES

- Define human performance as it pertains to the aviation environment
- Understand the influences of human perception on developing and maintaining situational awareness
- Discuss human perception and perceptual illusions leading to SD
- Review standard recovery procedures for SD

6

Figure 61. Instrument refresher course - objectives.

INSTRUMENT REFRESHER COURSE
(AIR COMBAT COMMAND)

- MISHAP ANALYSIS
- SITUATIONAL AWARENESS
- ATTENTION MANAGEMENT
- AIRCREW REACTION TIME

7

Figure 62. Instrument refresher course (Air Combat Command) (2).

INSTRUMENT REFRESHER COURSE
(AIR COMBAT COMMAND)

- PERCEPTUAL ILLUSIONS
  - VISUAL
    - RUNWAY WIDTH/LENGTH/SLOPE
    - TERRAIN TEXTURE/FEATURES
    - BLACK HOLE
    - APPROACH LIGHTING

8

Figure 63. Instrument refresher course (Air Combat Command) (3).

INSTRUMENT REFRESHER COURSE
(AIR COMBAT COMMAND)

- PERCEPTUAL ILLUSIONS
  - VESTIBULAR
    - LEANS
    - VERTIGO
    - GIANT HAND
    - G-EXCESS ILLUSION

9

Figure 64. Instrument refresher course (Air Combat Command) (4).

INSTRUMENT REFRESHER COURSE
(AIR COMBAT COMMAND)

- LOW ALTITUDE MISHAPS
- RECOVERY FROM SD
  - VISUAL DOMINANCE...VMC
  - VISUAL DOMINANCE...IMC
  - CONDITIONS RESTRICTING INSTRUMENT USE

10

Figure 65. Instrument refresher course (Air Combat Command) (5).

INSTRUMENT REFRESHER COURSE
(AIR COMBAT COMMAND)

- "MEJSA" PLANNING MODEL
  M-ISSION
  E-NVIRONMENT
  J-ET
  S-ITUATION
  A-IRCREW
- PRE-FLIGHT BRIEFING

11

Figure 66. Instrument refresher course (Air Combat Command) (6).

Training initiatives to overcome SD in the U.S. Navy

Captain Jonathan B. Clark gave this presentation. The text and figures are reproduced below.

TRAINING AND RESEARCH
INITIATIVES TO OVERCOME SD IN
THE U.S. NAVY

CAPT Jonathon Clark MC USN (FS)
Naval Aerospace Medical Research Laboratory
Spatial Orientation Systems/ Code 22
51 Hovey Road
Pensacola, FL 32508-1046

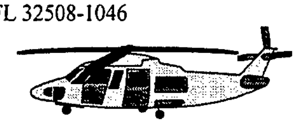


Figure 67. Title - CAPT Jonathon Clark

I'm going to be talking about training and research initiatives to overcome SD in the Navy. I throw in research because I'm from the research lab and much of what we do now is directed at supporting training initiatives. I always like this quote: " It's been said that good judgment is based on experience, but that unfortunately good experience is based on bad judgment." (VADM James B. Stockdale USN (retd) from "A Vietnam Experience"). Training is an attempt to obtain good experience without necessarily having to go through the course of bad judgment, by learning vicariously from others' mistakes. Much of what we do now in training is based on lessons learned by the tragedy of mishaps, and SD is a big component of that.

Ground based training

Our ground based training is composed of a number of different courses of instruction. The first is given primarily to the aeromedical personnel, that's the flight surgeons, physiologists and aviation experimental psychologists (figure 68). It is embedded in a 6 month course in Pensacola. The disorientation syllabus is 3 hours long, 2 hours of which is didactic instruction. Another hour is case presentations where we take actual mishaps and go through some of the teaching points, thus allowing people to get some experience using the terminology. Particularly, we talk about mishap investigation and how you would prevent this in the future. We also show a video tape on SD.

We're shifting to what I call "case-based instruction" which uses actual mishap scenarios. We talk about disorientation, the definitions, and the impact of disorientation. Certainly Desert Storm taught us some lessons there. We lost more personnel to disorientation mishaps than to direct enemy action, and it was primarily a rotary-wing problem. So SD is a killer, a show-stopper, and just as significant a problem as combat attrition losses. The basic Navy SD training

syllabus is reproduced at appendix D. The flight surgeons and physiologists can take back this information to the squadrons, cut and paste to their individual type airframes and use in a course of instruction at a squadron level.

Student Naval Flight Surgeon
Student Naval Aerospace Physiologist Ground based
SD training

- Naval Aerospace and Operational Medical Institute (NAMI) Academic Phase
- SD Syllabus in the Environmental Physiology Section
- Lecture (2 - 50 minute periods)
  - Introduction
  - Impact Of SD
  - Neurology Of Spatial Orientation Systems
  - Spatial Disorientation Illusions
  - Operational Aspects Of SD
- Case presentations (1 - 50 minute period)
  - videos of mishap footage, mishap computer simulations
  - UK RAF video (Puzzling perceptions)

Figure 68. Student Naval flight surgeon and student naval aerospace physiologist ground based SD training.

The next type of ground based training is for all aircrew and aviators. This is in the first month that aviators and other aviation personnel go through Pensacola. In Naval Aviation Schools Command, there is a course of instruction taught at the physiology training unit on disorientation and visual illusions (figure 69). This is a 2 hour lecture, taught by aerospace physiologists and aviation physiology technicians. One hour covers unaided night vision and visual problems and a discussion of visual illusions, followed by a 50 minute lecture on SD. They're trying to shift to more case-based learning, but presently it is more didactic. The physiologists and flight surgeons go through SD training twice in the first 6 months in both aeromedical training, and during generic aviator aircrew training. Hopefully by now they've picked up some of the aspects of SD. We use the Multi-Station Disorientation Demonstrator (MSDD) and the Barany Chair for SD demonstrations. In general, the MSDD is used for initial training, but not afterwards. The Barany Chair is primarily a backup to our MSDD, which I'll talk about next.

Entry Level Aviator/ Aircrew Training
Ground based SD training

- Naval Aviation Schools Command Aviation Indoctrination Phase
  - curriculum managed by Naval Aviation Physiology Training Program (NAPTP)
  - 2 - 50 minute lectures
  - Unaided Night Vision and Visual Problems (50 minutes)
    - Anatomy and Physiology of Vision/ Dark Adaptation
    - Visual Illusions
  - SD (50 minutes)
    - Input to Orientation Systems
    - SD (Vestibular) Illusions
    - SD Prevention and Recovery
    - Barany Chair Demonstration
      - Adaptation to Constant Rotation/ Coriolis Illusion

Figure 69. Entry level aviator/aircrew training ground based SD training (1).

Ground based demonstrators

The MSDD is a 10 station capsule on a 10 foot arm. This device is actually unique in the world. It costs about a million dollars. It was designed in the late 1970's and built in the early 1980's. Student aviators experience it in the first month of their academic phase (when they're getting just the basic of aerodynamics). They get about a 30 minute demonstration, 10 or 15 minutes is in the device and then the remainder of the time is spent observing what other people are going through. The purpose of this device is to establish the compelling nature of some visual and vestibular illusions. Again, because we can train a large number of people, we're able to enhance the training for everybody, so that everybody experiences these different types of illusions. The device has a fairly nice field of view that looks outward onto a screen that's about 60 feet from the center upon which you can project various visual scenes, primarily stripes and starlight patterns. The capsules can rotate in one of four positions facing in, out, forwards or backwards with respect to rotation. Students go through a number of the visual illusions, circular vection and autokinesis, the somatogravic and somatogyral illusions. Unfortunately, it's probably lost on these guys because they don't actually start the flight training phase for 4 months. Certainly a time that would probably be better for it would be during the instrument training.

Entry Level Aviator/ Aircrew Training
Ground based SD training

- SD demonstration (30 minutes as subject and observer)
- Multi-station Disorientation Demonstrator (MSDD)
    - establish compelling nature of perceptual visual and vestibular illusions
    - 10 subjects in variable position capsules on 10 foot centrifuge
    - 120 deg Horizontal x 40 deg vertical FOV
    - 120 deg/ sec angular velocity/ 15 deg/ sec2 angular acceleration
    - Visual Illusions (autokinesis, circular vection)
    - Vestibular Illusions (sub and suprathreshold stimulus)
        - Somatogyral illusion (Graveyard Spin/ Spiral)
        - Oculogyral illusion (cross coupled Coriolis illusion)
        - Somatogravic illusions (Pitch up, Pitch down, lateral tilt)

Figure 70. Entry level aviator/aircrew training ground based SD training (2).

As you know, Navy, Coast Guard and Marine aviators go through a full fixed wing syllabus prior to the rotary-wing syllabus (figure 71), so they get disorientation training in both fixed and rotary-wing in the instrument syllabus in ground school. The flight instrument manual is our bible as far as instrument training, where there is a section on disorientation, although it's quite dated. The discussion is mainly on the problems in visual meterological conditions (VMC)/IMC transition. A lot of time is spent on instrument scan pattern and what to do in unusual attitude recovery and inadvertent entry to IMC. There is not much on recognizing SD, but rather how to recover from it.

Initial Training (Student Naval Aviator)
Ground based SD training

- Training Air Wing Instrument Ground School
    - 2 week academic (classroom) phase
    - primary flight training (fixed wing/ T-34C)
    - advanced flight training (rotary wing/ TH-57)
    - simulators prior to Basic and Radio Instrument (BI/ RI) flight phase
    - NATOPS Flight Instrument Manual (NFIM) Chapter 19
    - covers areas related to SD prevention, recognition, and recovery
    - instrument scan, IFR/ VFR transition, inadvertent IMC

Figure 71. Initial training (student Naval aviator) ground based SD training.

We have refresher training every four years as required by our Naval Aviation Training Operating Procedure Standardization (NATOPS) (figure 72). Everyone on flight status receives it even while in a non-flying billet. There's a program manager in Pensacola who manages the syllabus, which is relatively standardized. Again, refresher training is two 50 minute lectures. Essentially, it's the same didactic lectures that were given in the introductory phase, with some aircraft specific case-based learning.

Ground based Refresher SD training
(Designated Flight Personnel)

- Aviation Physiology Training Unit (APTU)
- Refresher Physiology syllabus
  - required for all aviation personnel every 4 years
  - course of instruction same as Entry Level Aviator/ Aircrew Training
  - curriculum managed by Naval Aviation Physiology Training Program (NAPTP)
  - 2 - 50 minute lectures
  - Unaided Night Vision and Visual Problems (50 minutes)
  - SD (50 minutes)

Figure 72. Ground based refresher SD training (designated flight personnel).

The other aspect of ground based training that is pertinent to disorientation occurs in the instructor training unit (ITU) (figure 73). These people are the designated aviators who are going to be trained as flight instructors. During this ITU phase, there are several different levels of SD training, depending on the type of instructor. All instructors receive a 2 hour block in out of control flight (OCF) recovery and recognizing sensory perceptual problems. The most comprehensive level is given to the folks that are routinely putting their aircraft into unusual attitudes, that's the familiarization and acrobatics instructors. Our standardization pilots who evaluate the instructors also receive another 2 hours.

The extent of ITU instruction depends on what level of instruction the aviator is going to be administering. The vast majority of this training is on recovery techniques.

Instructor training
Ground based SD training

- Training Air Wing Instructor Training Unit (ITU)
  - Out of Control Flight (OCF) Syllabus
    - Basic Flight Instructors - 2 hours
    - Familiarization (FAM), Acrobatics (PA) / FORM Instructors - 4 hours
    - Stadardization Pilots (Instructor Examiners) - 2 hours
  - emphasize recognition and perceptual problems (spatial and temporal distortion)
  - discuss recovery techniques

Figure 73. Instructor training ground based SD training.

Flight based training

Flight based SD training is done by standard instrument pilots, not anybody with specialized aeromedical training. All Naval aviators go through fixed wing training first (figure 74).

Because all pilots in the Naval air forces receive this, the majority of disorientation training is embedded into the fixed wing syllabus in the T-34 single engine turbo-prop aircraft. Student Naval aviators receive a 1½ to 2 hour sortie focusing on unusual attitude recovery. It covers unusual attitude recovery using full and partial panel, and various things that are related to disorientation (inadvertent IMC, VFR/IFR transitions, etc.)

Initial Training (Student Naval Aviator)
Flight based SD training

- Training Air Wing
- Fixed Wing Flight Training Instruction
  - primary flight training (fixed wing/ T-34C)
  - Unusual Attitude Recovery
  - one sortie (1-2 hours)
  - part of Basic Instrument (BI) flight syllabus
    - covers areas related to unusual attitude recovery
    - using full and partial panel recovery
    - instrument scan, IFR/ VFR transition, inadvertent IMC

Figure 74. Initial training (student Naval aviator) flight based SD training (1).

In 1993, the rotary-wing side introduced a disorientation flight called the "SD vertigo recovery flight," (figure 75). It's approximately a 2 hour flight. The students are in a TH-57 in the right seat, with another student in the back. The latter is observing and listening to what's happening, so not only do they experience it as a pilot at the controls, but also as an observer. This disorientation flight profile in helicopters is the last flight of the basic instruments syllabus. Again, most of the focus is on unusual attitude recovery, but they also discuss crew coordination and recognition of disorientation. They also do full and partial panel recoveries.

Initial Training (Student Naval Aviator)
Flight based SD training

- Training Air Wing
- Helicopter Flight Training Instruction
  - advanced flight training (rotary wing/ TH-57)
  - SD/Vertigo Recovery (Unusual Attitudes)
  - one sortie (1-2 hours) as pilot at controls (PAC) and observer
  - part of Basic Instrument (BI) flight syllabus - last flight in BI phase
    - covers areas related to SD recognition and recovery
    - using full and partial panel recovery
    - instrument scan, IFR/ VFR transition, inadvertent IMC

Figure 75. Initial training (student Naval aviator) flight based SD training (2).

The flight instructors also receive flight based training in SD, as described in figure 76.

Instructor training
Flight based SD training

- Training Air Wing Instructor Training Unit (ITU)
- Out of Control Flight (OCF) Syllabus
  - instructor flight training (fixed wing/ T-34C)
  - All Flight Instructors - ATS, CCD, ZAD
  - FAM/ PA/ FORM Instructors
    - two sorties (2 hours) emphasizing recognition and recovery techniques
  - Standardization Pilots - one sortie (2 hours)

Figure 76. Instructor training flight based SD training.

The Navy's flight based SD training could be enhanced (in collaboration with the Army initiatives) so that we cover more prevention and recognition. Flight based SD training for instructors is tailored to the type of instructor, just as is the ground based SD training. All instructors receive training in approach turn stalls, cross coupled departures, and zero airspeed departures. The content may need to be improved, but it's hard to add a flight to the training syllabus because of the cost of training.

Research to support SD training

Now I'd like to briefly mention some of the projects that we have to support training (figure 77). One of these is the helicopter instrument scan project. We have a device that allows the instructor to actually monitor where a student is looking. This is one of the biggest problems - a real challenge to instrument training. Instructors know how to teach an instrument scan, but all they really have to assess success is performance measures; i.e., how well do they fly? Now we have a mechanism to say how much time they're dwelling on certain instruments, and the nature of their scan profile. This research project has been designed to improve instrument scanning by providing feedback on the actual instruments that are being looked at. Subjects who volunteered for the study were actually getting better grades, so there was a controversy as to whether they were getting a preferential advantage. There's no better argument to the success of a program than to actually demonstrate it while you're doing the study.

Another project we're working on is screening for disorientation-prone individuals. This is something that probably doesn't account for a lot of SD problems, but the only test of vestibular function we screen for is whether you can stand upright with eyes closed. We've been looking at student pilots who flunked out of instrument training. We found that they very often had some type of ocular motor tracking problem. So we're trying to find out if there's some means with which we can definitively assess people, and maybe we should use this as a screening test.

RESEARCH INITIATIVES TO OVERCOME
SD IN THE U.S. NAVY

- Helicopter Scan Project
- Dr. Temme/ Dr. Still (Vision Department)
  - Methodology to improve instrument scan by providing feedback on actual instrument scan pattern using an eye movement monitoring system in the helicopter simulator
- Vestibular Test Battery
- Dr. Clark/ Dr. Rupert (Spatial Orientation Systems Department)
  - Development of Vestibular Test Battery to screen pilots susceptible to SD

Figure 77. Research initiatives to overcome SD in the U.S. Navy (1).

A few other areas that we're researching to improve aviator training are shown in figure 78. We do computer simulations of mishaps and that in itself has training value. You can't always provide a video tape of a mishap. Often all you have is a smoking hole, but we have been able to recreate mishaps with high end virtual reality computer graphics. This visually demonstrates what the pilot experienced, and serves as a lesson. The vibrotactile orientation suit is described later.

RESEARCH INITIATIVES TO OVERCOME
SD IN THE U.S. NAVY

- Spatial Awareness Program
- Dr. Rupert (Spatial Orientation Systems Department)
- Development training paradigms and mishap investigation tools to improve spatial orientation and situation awareness
- Vibrotactile Orientation Suit (VTOS)
- Dr. Rupert/ Dr. Raj (Spatial Orientation Systems Department)
  - Development of an undergarment suit to provide tactile cues to improve situation awareness (earth vertical from attitude indicator, altitude from RADALT, threat location from RWR gear, drift from doppler/ GPS)

Figure 78. Research initiatives to overcome SD in the U.S. Navy (2).

In conclusion, I think the areas that we're concerned with are shown in figure 79. To improve the content of our training, we need to add more case based training. In other words, trying to show actual mishap examples to reinforce the disorientation point. Clearly the timing of our instruction is not well suited to optimize disorientation training. For example, the MSDD is done 3 or 4 months before students start basic ground school. With regard to training, the MSDD doesn't have any feedback loops, so the pilot can't control anything. That's a deficit in which the USAF ASDD will probably be much better. I think the key to this is to shift from a demonstration mode to a training mode. Finally, flight based SD training has got to be embedded into operational flying or other phases that are already currently available. We're not

going to have the advantage of saying, "Let's add an extra SD flight," it's just too costly. We're going to have to integrate our training syllabus into existing flight training.

CONCLUSIONS

- Content
  - Ground based SD Training (instructors and aviators) shift from lecture to case based training
- Timing
- SD Demonstration device used during basic instrument phase vice entry level only
- Realism
- Ground based SD devices shift to training device with pilot input vice demonstration device only
- Cost effective
- Flight based SD training embedded into instrument training and operational flying

Figure 79. Conclusions

Training initiatives to overcome SD in the USMC

Commander Rick Mason gave this presentation. The text and figures are reproduced below.

USMC TRAINING INITIATIVES TO OVERCOME SD IN ROTARY WING OPERATIONS

CDR RICK MASON
3D MARINE AIRCRAFT WING
DSN: 997-4013

"The best audience is intelligent, well educated, and a little drunk."
Will Rogers

Figure 80. Title - CDR Rick Mason.

As far as our ground based training is concerned (figure 81), the USMC does much the same as the Navy since we're in the Naval aviation program. The Naval Aviation Physiology Training Program (NAPTP), is a quadrennial (every 4 years) requirement and our pilots have to undergo this training. There is also an annual instrument ground school requirement. For the USMC, there is another requirement to have a physiologist or flight surgeon do a brief on SD. This is mandatory, so it's pretty easy with a relatively small group of people in a small concentrated area to standardize training initiatives and get things going.

GROUND BASED TRAINING

- SAME NAPTP REQUIREMENTS AS USN (PILOTS/AIRCREW)
- ANNUAL IGS LECTURE (PILOTS)
- NITE LAB (PILOTS/AIRCREW)
- FS (SQDN)/AMSO (MAG/MAW) TEAM AVAILABLE TO COMBAT "HUMAN FACTORS" MISHAPS(PILOTS/AIRCREW)

"Ignorance doesn't kill you....but it sure makes you sweat a lot."
Haitian proverb

Figure 81. Ground based training.

I think that a big issue that needs to be talked about is making sure that we're optimizing the use of sensors. The USMC has done that through the use of the night lab program, which consists of basic information on the use of NVGs, and as we get into navigational FLIRS, we'll start doing that, also. The Marines have invested a lot in the human factors team. Every

squadron has a flight surgeon and every Marine Air Group and Marine Air Wing also have a physiologist acting as an aeromedical safety officer. So for "pop-up" briefs and in dealing with actual concerns on a day to day basis, there's a pretty good human factors team to address some of these issues. Not just disorientation, but anything else that is topical.

As far as training devices are concerned, we use the Navy's facilities (figure 82). The one thing that we have done, and this is a proof of concept project, is something that we're calling simulator physiology (simphys). We're taking our didactic training that is currently done in the classroom and we're putting it into a simulator case-based scenario. We did a proof of concept with the AH-1W simulator, where we have instructors come into the classroom and give pilots a flight brief that includes the choice of four potential co-pilots or wingman to choose from. There are significant levels of human factor and physiological concerns in their 72 hour histories that they have to find out about. The interesting thing as far as disorientation is concerned, is that we go into the simulators (a 1.5 hour hop), which includes going out to the boat, both in good and bad conditions as far as sea state is concerned, and loss of visual horizon (so we have the concern for false horizons and the induction of disorientation). We also have pilots fly inadvertent IMC, which is pretty interesting. That particular scenario is based exactly on the parameters that occurred in a 1991 mishap where a Cobra section tried to come back via a ground controlled approach (GCA), which was unauthorized. Dash 2 just happened to be the Squadron CO, rolled inverted and flew into the ground. It was absolutely unnecessary. The simulator guys have found out that it is usually the most experienced guys who go inverted. It wasn't the junior guys, because they would realize their limitations, break off and say, "Hey, this is beyond my capability," whereas the more senior pilots would just try to tuck in tighter and tighter and then they would go inadvertent IMC. So using the lead aircraft as your point of reference, he disappears and you're in a turn and it's almost subthreshold. By the time the guy realizes what's going on and transitions to instruments, it's usually too late and he's already rolled the aircraft inverted. So that's been a pretty good learning tool for us. As a result of this effort, the squadrons have expressed more interest in trying to get more and more simulator experience for instrument flying and testing. So it may actually become part of the instrument qualification, which is an airborne demonstration.

SD TRAINING DEVICES

- SAME AS USN
- SIMULATORS--SIMPHYS

"Life is tough and it's tougher if you're stupid." John Wayne in "Sands of Iwo Jima"

Figure 82. SD training devices.

As far as the evaluation and standardization is concerned, our NATOPS jacket, which is our standard training jacket, is a one-stop shop for standardization purposes (figure 83). You can see if the guy has all the training requirements necessary to fly the aircraft on that particular day. USMC also has aircrew performance records which govern training and readiness. The USMC has every one of its flights coded. In other words, when you go out on a flight and you perform certain evaluations, it counts towards the combat readiness percentage. Every flight, when it goes on the flight schedule, has learning objectives coded into the flight syllabus and onto the actual flight schedule. It allows the scheduling department and the operations staff to know exactly where a person is in regard to their training requirements and their proficiency.

TRAINING EVALUATION

- NATOPS JACKET DOCUMENTATION
- MODEL MANAGER EVALUATIONS
- COMBAT READINESS PERCENTAGE (TRAINING & READINESS MANUAL)

"The average person thinks he isn't." Father Larry Larenzoni

Figure 83. Training evaluation.

There's a training and research initiative that is looking at computerizing personal data so that when a schedule writer puts a person in for a flight, it automatically flags it and says "No, you shouldn't fly this person with that person because of the experience level you're matching up in the cockpit." So it looks like a pretty good risk management tool and it should help towards some of the potential concerns we talk about, particularly crew coordination in regard to disorientation.

All of these programs, whether it be aircraft, physiology, or instrument ground school, have model managers, which I believe would be the same thing as the training standardization brigades on Fort Rucker.

As far as airborne demonstrations are concerned (figure 84), there is no standard demonstration syllabus for any of the type models. There are maneuver description guides for the various airframes that will tell you how you're supposed to fly various maneuvers, and you're supposed to fly at that level of proficiency in accordance with the training readiness (T&R) manual requirement. The one thing that the T&R manual does allow for is the building block approach so that you're not going to schedule someone for a hop that they're not ready for. They have built in requirements for what we call "turf terrain" following, which gets down to the nap

of the earth (NOE) environment. For NVGs, the USMC and the Navy have light level differences in the training requirements.

AIRBORNE DEMONSTRATIONS

- NO STANDARD DEMONSTRATIONS
- MANEUVER DESCRIPTION GUIDE
- TRAINING AND READINESS MANUAL
- BUILDING-BLOCK APPROACH (TERF & HLL/LLL SYLLABUS

Figure 84. Airborne demonstrations.

Discussion Session

The discussion at this session was transcribed from audio tape. Questions are prefixed by "Q," answers by "A," and interjected statements by "S."

S - Lt Col Braithwaite. There seem to be training initiatives going on in each of the services. There isn't any great commonality in those initiatives, but everybody seems to be thinking about how to try to improve things. I hope this symposium has concentrated the minds of those who need to continue to audit training and make improvements. We heard yesterday on the size of the SD problem. It's time to do something about it. I'd like to particularly hear from the flight safety officers and flight surgeons in the audience about what you feel about the current state of training, and how we can make it better not only at centralized institutions like the School of Aviation Medicine, but perhaps more importantly out in the unit as part of your refresher training.

Q - CPT McMullen. Lt Col Braithwaite, you said that the flight surgeons in the U.K. run the SD demonstration sortie and you actually fly the aircraft at the same time?

A - Lt Col Braithwaite. Yes, we are qualified pilots as well. We have adapted this sortie to demonstrate to the U.S. Army by having an IP do the flying, with a flight surgeon up front conducting the sortie once he's told the IP what to do next.

Q - CPT McMullen. How will you handle that with Longbow pilots?

A - Lt Col Braithwaite. We do not intend to fly the sortie in the Apache. It can be done in a small, generic helicopter. In the U.K., we use the Gazelle, at USAARL we are using the UH-1. You need some sort of aircraft where you can get three passengers in the back as well as two crew members up front.

Q - CPT McMullen. At Fort Hood, we get called in when pilots over-torque their Apaches. They'll be in a hover doing live firing or something for a long period of time, and they'll get SD, find that they're losing altitude and don't realize it, or they pull up on the collective too hard and over-torque the aircraft. We're trying to find a way to help them. Will the training sortie that you do help them with this type of problem?

A - Lt Col Braithwaite. It will certainly demonstrate the limitations of their orientational senses in flight and make them more aware of the situations in which SD will occur. As I said yesterday during my presentation on the impact of SD, this sort of incident is extremely frequent. I must stress though, that the sortie I described is a demonstration sortie and not a training sortie when the pilot is instructed on what to do when SD occurs. That's the IP's responsibility. The situation you're talking about could possibly be addressed in simulators. Perhaps we need to start thinking about simulator training programs to show people that this is a problem in a particular type of aircraft. Firstly, don't get into that type of situation and secondly, how to overcome it.

Q - Cdr Rick Mason. Does anybody have a decent simulator that has "brownout" or "whiteout" that looks realistic?

A - Lt Col Braithwaite. The USAARL UH-60 has "brownout." (Ed note: since the symposium, the USAARL UH-60 simulator can now also simulate "whiteout" [other UH-60 simulators may also have the same digital image generation capability]).

Q - LTC Jeff Hill. Rick (CDR Mason), I have one for you. We had an accident a couple of years ago involving an H-60 which hit some wires and a lot of questions were asked about the Air Force tracking NVG hours. How do you track that in the USMC?

A - CDR Mason. I'm not sure how the Army does it, but when our pilots come back and fill out their flight log sheet, they log in NVG, and they are logging low-light level and high-light level. We actually have two tracking systems so just a review of a guy's log book will tell you how many NVG hours he has in low-light level or high-light level; plus the T&R manual matrix will let you know what type of flight he was doing, troop lifts or whatever.

Q - CW5 Irwin. I'm the Aviation Training Brigade Safety Officer. You mentioned this automated system where your operations person allocates pilots to fly missions.

A - Cdr Mason. We don't have it yet. It's being looked at right now at the Harrier community at Yuma. But that's the intent. You put a name into the computer and say, "Okay, I want to fly this person with that person," then as you go into that T&R matrix, it will flag and say, "I wouldn't fly these two guys together because this person didn't fly this level hop and hasn't flown one for 9 months - he may be current but he may not be proficient." So, mixing and matching the crews becomes a much easier process.

Q - CW5 Irwin. But this is something that the system that you're proposing can do, so the commander can go through and start putting in names and all of sudden it will kick it back out.

A - Cdr Mason. Absolutely.

Q - CW5 Irwin. Is there a commander's override in this?

A - Cdr Mason. The CO is always going to review the flight schedule. He has to sign it. So he may say, "I don't want these two guys to fly together." I haven't seen the program at that level of detail where you can start putting in squadron limitations as opposed to the limitations governed by the rules and regulations.

Q - CW5 Irwin. The reason I mention this is that we've been working on an automated night risk management system. It's supposed to identify a lot of the cause factors and problem areas and put in controls. I was just wondering if yours is working in conjunction with this or are we both working on something along two separate tracks.

A - Cdr Mason. Is your system based upon your risk management matrix? The USMC abhor the whole system. They don't want a number telling them they're supposed to go to a certain command level to authorize the flight. They're not convinced that you can sit there and say that this is going to be a higher risk just based upon numbers, as opposed to experience and gut feeling. I guess CPT Almond can address this more since this is a Naval Safety Center issue. We're getting more into operational risk management.

Q - CW5 Irwin. The next question I've got is for CPT Clark. You had mentioned earlier that you always play back the accidents in the simulator. Are all Navy aircraft equipped with flight data recorders?

A - Capt Jonathon Clark. No, unfortunately, only the newer aircraft, and I think Malcolm Braithwaite mentioned this earlier. The tools, like the mission data retrieval system, are primarily for the maintenance crews to look at maintenance cycles for various components: airframe stress, landing cycles, things like that. That's only available on our newer aircraft like the F-18 and some of the other ones. No helicopters have that system and very few fixed wing have it. I think as newer things come on line, this will be taken into consideration, but its got to serve multiple purposes. One would be for the maintenance folks to review the stresses and strains on the airframe. Another would be to review the flight profile as part of the mission debriefing, and then finally in the worst case scenario that you had a mishap, it would give you a mechanism to fill in the data points as to what the aircraft did before it impacted. You won't be able to sell it purely as a flight data recorder, it's got to handle maintenance records and mission debriefing. We do mishap recreations based upon known data like radar data points. The takeoff and landing points on all of our carriers are video taped for that reason. Some of the aircraft have tape recording HUDs, like the F-18s. Then we try to give our best guess as to what happened in the mishap and essentially try to recreate the flight profile. We might fly it in the simulator to fill in some more data points, and then let the computer recreate it. So, they can say, "What if

they were at this attitude?" and so on. It allows you to use various parameters to see what might have happened. Then we look at it perceptually from what the pilots experienced. The Silicon Graphics computer allows you to download a visual database of the whole world from satellite imagery. So you can actually input the scenery of the local mishap area. Most of the ones we've done have been really impressive.

Q - CW5 Irwin. The reason I ask this is because we've found that the flight data recorder in the UH-60 has been a real help in finding out exactly how this guy lost this aircraft.

S - Lt Col Braithwaite. Can I bring this back to training so we can have a break? As we did yesterday when we all agreed that SD has a significant impact upon flight operations. I would like to do the same now by saying, "Does anyone disagree that reviews and revision of training in SD in all its context, and that's everything from ground lectures, ground based devices, airborne demonstrations, airborne training, review and revision should continue?" It seems to be happening in most of the services. Are there any dissenters amongst us that would like to offer an opinion that everything is fine and we don't need to do anything? (Ed comment: there was no response). Good, let's agree to agree on that, anyway. There is room for triservice cooperation, and I know that USASAM has offered to coordinate all aspects of aeromedical training, but to maintain the impetus improvements must start now within the single services. I do appreciate the opportunity that we've had to hear about everyone else's experiences so we can all learn from each other. There is contact through the triservice working group to cross-fertilize ideas, and so on. I look forward to some improvement.

Q - Mr. Mike Moran. One quick question - is there going to be generic recommendations from the triservice work group?

A - Lt Col Braithwaite. Not necessarily. My personal feeling is that we should attack the Army SD training within the Army first, and we can gain from the experiences of the other services to help the lot of aviators within each service.

Q - Mr. Bill Ercoline. Since we have some of the experts in training here, I'd just like to get an opinion because USAF is struggling with the frequency of training. Are there any thoughts by the panel members on how often a pilot should be exposed to refresher training?

A - Lt Col Braithwaite. The proposed air standard on physiological training in SD recommends a 4 year cycle. I drafted this air standard which had all Air Standardization Coordination Committee's curricula, and that was the longest cycle that people actually said that they did refresher training.

Session 3: Technology initiatives to assist spatial orientation in flight

Following the session on training initiatives, this section addressed the enhancement of the awareness of the nature of SD and predisposing conditions in flight. There are two aspects to be addressed. Firstly, the improvement of the aviator's ability to perceive and maintain correct spatial orientation in flight; and secondly, to aid recovery to the desired flight parameters, should SD occur.

To date, the means to maintain orientation when external visual cues are absent or degraded has been to refer to the standard array of flight instruments and make them read what we want. However, there are problems with this system. The information for correct orientation might be there, but do we attend to it, and does it get to the part of the brain that we want, especially when there are many other things to which to attend in order to maintain overall situational awareness?

Three presentations were made in this section:

Vibrotactile Interface by Dr. Anil Raj, of Naval Aeromedical Research Laboratory, (NAMRL).

A Novel Instrument Display by Lieutenant Colonel Malcolm Braithwaite, USAARL.

3D audio by Dr. Tamara Chelette, Armstrong Laboratories, Wright Paterson AFB.

The presentations are not recorded in these proceedings. For further details, please contact the authors, who will be pleased to direct the reader to the appropriate publications.

Session 4: Classification of the SD mishap

Introduction

We heard in the session on the impact of SD on our rotary-wing operations that there was probably an underestimate of the true representation of the size of the problem because of difficulties in classification of accidents and incidents.

This final session is dedicated to examining the different ways of recording the phenomenon as seen by the different services, and then to trying to assist ourselves both within a single service, but perhaps more importantly, throughout the services. The ultimate aim would be to achieve the following:

- accurately record the number of accidents in which SD is implicated.
- thence, compare accidents involving SD with other accidents in order to determine the particular patterns associated with SD accidents.
- and ultimately, to identify areas for further research and control of the problem.

Classification of the Army SD mishap

Lieutenant Colonel Ed Murdock gave the following presentation.

We're going to talk about classification of Army SD mishaps. In the Army, we do have a code for SD, but how effectively do we apply it? I did a review of accidents in the Safety Center database from 1983-1992 and I was able to extract 54 SD accidents from that time frame. Lt Col Durnford, in a 5 year period (1987-92), by going through and reading each of the accident reports, classified 187 accidents as having SD as a major or contributory factor. (Ed note - see Braithwaite "Impact of SD on Army Rotary-wing Operations" for these definitions). So what I've realized is that even though we do have a Safety Center code for SD, there is little knowledge out in the field of either recognizing SD, or saying on a mishap investigation board that it should be included in the summary of one of the findings. This is something that we have not mastered and I need to work on. Fortunately, I can now go back and pull what we've coded as SD, look at what Braithwaite and Durnford have coded, and find out what words I need to use to then extract all these others. I think, as indicated by Lt Col Braithwaite, words such as "scanning," "failure to scan the flight path" and "crew coordination" are going to be the ones that are going to enable us to start tapping in to that part of the database that we weren't able to do before.

What I'd really like to present are some of the issues that I'm going to be hopefully addressing about how we address the SD problem in the Army. As I've just told you, I don't think right now that we have a handle on it within our database. The information is in the database, the question is being able to draw it out and then draw conclusions as to what we need to do.

Firstly, our definition for SD is archaic and we are going to be recommending to USASAM (the proponent for the FM) that we accept the SD working group's definition.

Another issue is that, once we've identified an accident as being SD by this definition, how will we classify the type of SD? I would like to call type 1 unrecognized, type 2 recognized, but type 3 suspected. The first two are simply a direct lift from the way that Ernsting and King define it in their book on Aviation Medicine in 1988. The addition that I want to make is saying type 3 SD is "suspected." I feel uncomfortable with the USAF definition of type 3 SD as being "incapacitating." This is just me, and is not to say that this does not match USAF's mission or satisfy their needs, but when I was looking into the SD problem, I honestly felt that type 3 SD (incapacitating) can be a subset of both type 1 and type 2 SD. The reason being that you'll find in the references that type 3 is listed as being potentially recognized or unrecognized. You'll remember that when Lt Col Braithwaite went through the schematic that relates type 1 and type 2 SD, these situations already fit into the classification that is recommended by Ernsting and King.

LTC Murdock then gave some examples of type 1 and type 2 SD mishaps.

Type 1 (unrecognized)

Blown grass producing a vection illusion to a helicopter pilot who allowed his aircraft to drift from its datum over the ground and then impacted sloping terrain.

Type 2 (recognized)

Failure to maintain control of the aircraft during inadvertent entry to IMC.

Type 3 (suspected)

An accident which, for reasons of investigation, can't be classified as type 1 or type 2 SD. This is normally the case when there is a "smoking hole" and no survivors. However, by virtue of a witness statement describing the flight profile, it appeared that there might have been SD. Why does one even have an interest in these type of accidents? Because we need to document those type of accidents where fixes such as flight data recorders might help to give the investigators more information as to what really happened.

Classification of the Navy SD mishap

Captain Myron Almond gave the following presentation.

I'm going to be very mechanical. When I read the outline plan that Lt Col Braithwaite produced for this talk, it said "How do you classify SD mishaps in the Navy?" That's what I'm going to talk about. When the investigation board gets together, what are their options and how do they classify them?

First of all, let's talk about how the Navy investigates mishaps in general. We use something called an aircraft mishap board. At least four commissioned officers are on the board. Three of them are from the local squadron. They have a standing mishap board that trains and is ready to have a mishap investigation. One of them must be NATOPS manual qualified in that specific airframe. The others, in general, have to be an aviation safety officer, a flight surgeon, and a maintenance and operations officer. The board is augmented by a Naval Safety Center representative. We send someone out on most mishaps, if there's a plane. If it sinks in 50 thousand fathoms of water, we're not going to send somebody out. But if it's a Class A million dollars or fatality and there's some mechanical wreckage to look at, to salvage, etc., then we'll send a representative out. This Safety Center officer is not a voting member, but someone who's been to several mishaps and gives these people some help because members of the board may be attending their first mishap. Many flight surgeons will attend only one or two mishaps in their whole career, but the Safety Center representative has been trained and has been to 50 or 60 accidents. He is a direct representative of the Chief of Naval Operations, and "owns" the wreckage. So it's helpful to have him there.

The senior member of the mishap board has to be an O-5 or above and has to be outside the chain senior to the people that have crashed. Then the aircraft mishap board submits a mishap investigation report that goes up the chain of command and is endorsed by the Naval Safety Center. So the Safety Center representative, although non-voting, can say, "I would encourage you to look at it this way, because when I give my oral pre-brief to the Admiral, it's a good chance he's going to agree with me."

The aircraft mishap board then comes up with causal factors for each and every mishap. They're divided broadly into human causal factors and materiel causal factors. For each and every accepted causal factor, this is the structure that's used.

Who? Specifically, either personnel or equipment.

What? The actions or events that happened.

Why?

"Who, what and why?" In the Naval Aviation Safety Program book, (which is about to be revised) there is a menu at appendix L. They call it an exhaustive menu of all the "whos," "whats" and "whys" that can be used. In the "who" section, everyone can be included, but there's only certain "whats" you can use. And then there's a bunch of "whys." But you've got to pick out one of those "whys." You can't just make up your own "why."

The "whos" can be aircrew, supervisory, facilities, or maintenance. Of course in our context, we're talking about aircrew being in the "who" category for the SD mishap.

"What?" If you look under what happened and things that apply to the SD context, you'll see a list of about 20 things. But they all basically go like this: they misjudged the closure rate, the altitude above the ground, the distance between aircraft, landings on clearance misjudgment, landing roll out distance, etc. There's about 10 others, but they all have to do with misjudgment. So "who?," the aircrew; "what?," misjudged something, which of course ended up in a mishap. They had a mid-air, or they ran into the ground, or something. And then, "why?" You can assign a lot of "whys." But the "whys" that we are talking about are not communication, coordination, psychosocial, environment, performance, or human engineering, but medical and physiological.

So "why?" Because of some medical and/or physiologic problem. Then if you look under the medical and physiological area of the menus (again this is very algorithmic), you'll find things like acute effects of a cold, or chronic effects. Further on, you see vestibular illusions, other types of illusions and then SD, recognized or unrecognized.

So in theory, it would be very easy to go to our database and look for just "whys" and find all the ones that have SD recognized or unrecognized, because those are the only words that can be used in the Naval Safety Center's database to describe what we're talking about. However, basically you see "who." Human error was made by the supervisor or the aircrew, or the materiel and maintenance. This is very good at describing who made the human error. But if you go back into that database and try to pull out all the SD helicopter mishaps for the last 6 years, you find zero, when in fact there were at least three and perhaps four and five that we found other ways. This is primarily because the "why" has not been coded well.

We have an alternative that we have started using during the last 6 months. We developed a database, or more precisely, a human error model. The database is not official, it's just a survey we've done and have presented in many places. In that database, aeromedical comes under "unsafe aircrew conditions." What we've done is for every one of those causal factors, "who," "what" and "why," is to create a bunch of "whys." Each one of those causal factors has been looked at by multiple psychologists and the analysts for that particular airframe who said that this is the type of human error that was involved here. When reviewed by other people, they have been able to say that the aircraft crashed because of this "who, what, and why." So, let's interpret that in this model's context and come up with a causal factor based on the human error model. The model has been proposed by Reason, Chappell, and Wigman, people that have a lot of knowledge in this area. When we use this model to classify the accidents, 27 percent of all the 102 mishaps involved aeromedical factors. We can then pick out the SD accidents.

Classification of the USAF SD mishap

Mr. Bill Ercoline gave the following presentation.

CLASSIFICATION OF THE
USAF SD MISHAP

BILL ERCOLINE
SYSTEMS RESEARCH LABORATORIES

ARMSTRONG LABORATORY
SPATIAL DISORIENTATION COUNTERMEASURES TASK GROUP
BROOKS AFB, TX 78235

"SD in the Operational Rotary Wing Environment"
for the USASAM
24-26 Sep 96

Figure 85. Title - Bill Ercoline.

I could summarize this presentation by saying that in the USAF, a mishap gets labeled as SD providing two things occur. The first is that the investigating flight surgeon has the knowledge and can then recognize that he's dealing with an SD mishap. Second, he must log his finding on the mishap form, the 711gA. Then it becomes an SD mishap. It's not easy for both of these events to occur. The first is dependent on knowledge, and the second can become a political issue; the flight surgeon has to convince the rest of the investigation board. That can be an interesting time for some flight surgeons. It's not just a matter of checking the box.

We don't all perceive illusions in the same way. This in itself contributes to the classification issue. (Mr. Ercoline then presented two visual illusions and demonstrated the difficulty of interpretation.) We may all agree that something is an illusion, but when it becomes marginal, we then have a problem because it may not be a visual illusion to two people. Hence, a classification problem. It's often tough to properly define an illusion, particularly in words. It is even possible to condition yourself that it doesn't become an illusion on subsequent occasions.

Mr. Ercoline then related his first personal encounter with SD, and emphasized that a personal incident really brings home the problem of SD to an aviator.

I'll talk a little about some of the classification issues, some of the historical work that has been done, and how people have viewed SD in the past. This issue has been around for a long time and we're still struggling with it.

BACKGROUND

MAJOR AIRCRAFT ACCIDENTS

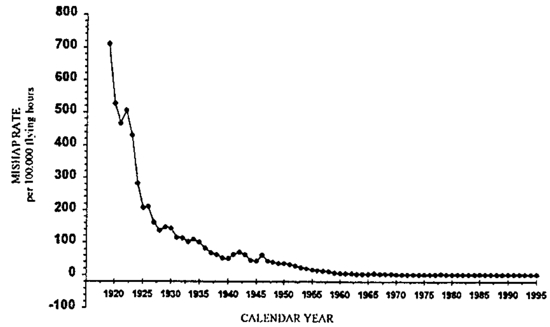


Figure 86. Major aircraft accidents.

We can look back at mishap rates since the American Services started to fly (figure 86). You can see how well we've learned to fly airplanes. Around 1926, William Ocker invented the Ocker Box, which showed how you could be disoriented. This was termed pilot vertigo. In the 1950s we started calling it SD. Good instrument training began around World War II and the mishap rate fell. Overall, the accident rate decreased by 95 percent from the 1920s to the 1950s (from 700 mishaps per 100,000 flying hours to 36). The Air Force Safety Center then thought we wouldn't match this dramatic decrease again, but when you calculate the reduction from the 1950s to now, we have had a further 96 percent decrease. The safety record is really quite remarkable. The mishap rate is now down to between 1 and 2 accidents per 100,000 flying hours. There's a lot of good being done, but we don't want to overlook the issue of SD. Because of the improved overall safety record, we often overlook the SD issue. It doesn't really hit home until you're a member of the accident board.

BACKGROUND

SD STUDIES

Authors	Years	SD% of Total
Barnum & Bonner (USAF)	1958-1971	6%
Moser (ADC)	1964-1967	9%
Kirkham et al (US Civ)	1968-1975	2.5%
Bellenkes et al (USN)	1980-1989	5%
Vyrnwy-Jones (USA)	1980-1987	14%
Singh & Navath (Indian AF)	1980-1987	2.5%
Holland (USAF)	1980-1989	12%
Lyons et al (USAF)	1990-1991	14%

Figure 87. SD studies.

Figure 87 illustrates some SD studies. There have been more, but these are the ones that Col Lyons and I went through. In Kirkham's civilian study, SD was the third leading cause of mishaps. The second leading cause in that study was flight continued into weather conditions (around 4 percent).

The variation of the incidence of SD over the years has been very dependent on the definition. For example, Barnum and Bonner defined SD as a "state of confusion" (figure 88). This is strictly **recognized** SD, where the pilot has to be confused and has been alerted to his state. Lyons, et al. used a definition which included an erroneous sense which could be no sense at all. In other words, this included **unrecognized** SD. So maybe because of the change in definition, we're looking at more numbers.

BACKGROUND

SD DEFINITION

- Barnum & Bonner

  SD -- a state of confusion concerning the airman's true position in space with reference to the earth's surface or other airborne objects

- Lyons, et al

  SD -- a state characterized by an erroneous sense of one's position and motion relative to the plane of the earth's surface

Figure 88. SD definition.

Figure 89 is an excerpt from the 711gA. The top part is the 1976 version, and the bottom is what we've had since 1989. In the 1976 form, the flight surgeon could only check the SD/vertigo box and rate it as definitely, contributed or suspected. Nowadays, we have just inserted SD types I, II and III under sensory and perceptual factors. If the flight surgeon does not put in the code for SD, it will not be an SD mishap. How well the form is completed is very important. We know that there are SD mishaps that haven't been properly coded.

BACKGROUND

Excerpt from AF FORM 711gA, Sep 76

ID ENVIRONMENTAL FACTORS

PHASES OF MISHAP
A - ACCIDENT
E - ESCAPE
L - LANDING
S - SURVIVAL (Includes parachute landings)
R - RESCUE

FACTOR IMPORTANCE
D - DEFINITELY CONTRIBUTED
S - SUSPECTED FACTOR
P - CONDITION PRESENT, BUT DID NOT CONTRIBUTE TO ACCIDENT OR INJURY

FACTORS		A	E	L	S	R
VISUAL ILLUSIONS	613					
UNCONSCIOUSNESS	614					
DISORIENTATION/VERTIGO	615					
HYPOXIA	616					

Excerpt from AF FORM 711gA, Aug 89

2 SENSORY AND PERCEPTUAL

115 VISION DEFICIT
116 VISUAL ACQUISITION
117 VISUAL ILLUSION
118 VESTIBULAR ILLUSION
119 KINESTHETIC ILLUSION
120 AUDITORY CUES
121 NOISE INTERFERENCE
122 VIBRATION
123 MISPERCEPTION OF SPEED
124 MISPERCEPTION OF DISTANCE
125 MISPERCEPTION OF POSITION
126 SPATIAL DISORIENTATION (TYPE 1) UNRECOGNIZED
127 SPATIAL DISORIENTATION (TYPE 2) RECOGNIZED
128 SPATIAL DISORIENTATION (TYPE 3) UNCONTROLLABLE
129 OTHER

Evaluate each factor for presence and the significance of its contribution. Mark PRESENT Factors with either 0, 1, 2, 3 or 4 from contribution scale. If Factor NOT PRESENT leave blank, if UNKNOWN if Factor PRESENT mark with "U".

NONE 0 — 1 — 2 — 3 — 4 DEFINITE

DISCUSS PRESENT FACTORS IN THE HUMAN FACTORS PORTION OF THE NARRATIVE

Figure 89. Excerpt from AF FORM 711gA, Sep 76.

Figure 90 illustrates the statistics over the years for all USAF Class A mishaps. The SD rate has gone down from 0.35 to 0.21. It tells us that for every 500,000 flight hours, we're going to have 1 SD mishap. The USAF flies about 2 million hours a year, so they're going to lose 4 airplanes due to SD.

DATA/STATISTICS

USAF SD CLASS A MISHAPS

Years	Total Accidents	SD Accidents	% SD	Total Flight Hours	SD Mishap Rate
* 1958-68 (11)	4,679	281	6.0	79,494,987	.35
1980-87 (8)	524	61	11.6	26,898,849	.23
1988-95 (8)	347	44	12.7	23,424,558	.19
or					
** 1980-95 (16)	871	105	12.1	50,323,407	.21

500,000 Flight Hours = 1 SD Mishap

* Barnum and Bonner
** AFSA

Figure 90. USAF SD Class A mishaps.

The total accident rate is going down (figure 91), and though the SD rate doesn't decline as quickly, it also is going down. If one extrapolates the data, the graph will hit the zero line at about 2040. So is SD still a problem? I think most of us feel that it is.

DATA/STATISTICS

Mishaps per 100,000 Flying Hours

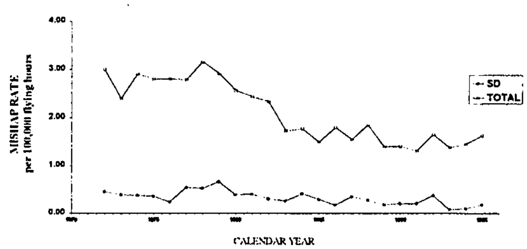


Figure 91. Mishaps per 100,000 flying hours.

Figure 92 shows that the average cost in resources (not lives) is high.

DATA/STATISTICS

Average Cost of a USAF SD Class A Mishap

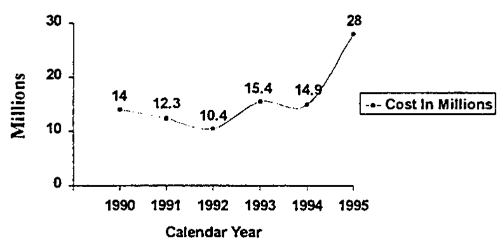


Figure 92. Average cost of a USAF SD Class A mishap.

Figure 93 gives the rotary-wing numbers from the data that we have. We looked in the 711gA at "sensory and perceptual" factors graded at 3 or 4 (essentially those that contributed significantly to the mishap). There are so few mishaps because we don't have a lot of helicopters.

DATA/STATISTICS

USAF ROTARY WING CLASS A RESULTS
(OCT 85-NOV 95)

All aircraft: 151 coded "sensory and perceptual" factors (3 or 4)

Helicopters: 8 coded "sensory and perceptual" factors (3 or 4)
3 of 8 coded SD, 5 not coded SD
- 2-Visual Acquisition
- 1-Auditory Cues
- 1-Geographic Disorientation
- 1-Misperception of Speed

Figure 93. USAF rotary-wing Class A results.

In summary (figure 94), perhaps the classification issue can be solved with an agreed SD definition. One is long overdue. SD mishap rates are decreasing, and it is easy to surmise that we are doing a better job. However, I urge caution. We are flying fewer hours. The relationship between total hours flown and the number of SD mishaps has never been established. It should not surprise anyone to find the relationship non-linear. We do know that SD is still a killer. The SD Countermeasures Group of the USAF feels that SD is the single most important cause of pilot related accidents. There is reason to suspect that it also has an impact on flight performance in general.

SUMMARY

- SD Definition Remains a Classification Issue
- SD/Mishap Rates are Decreasing
- Actual Impact of SD Unknown
- SD is Still a Killer

Figure 94. Summary.

Discussion session

The discussion at this session was transcribed from audio tape. Questions are prefixed by "Q," answers by "A," and interjected statements by "S."

Q - Unidentified (presumably an Army attendee). I have had a Navy crash happen near to me. Can we have a point of contact for sister service mishaps?

A - Lt Col Neubauer. For the Air Force, call the safety office of the nearest AFB and they will mount a response to the accident.

A - LTC Murdock. The Army Safety Center has a 24 hour number. If you call us, our operations people can notify other services.

Q - Capt Almond. For the Air Force - When you talk about a mishap that may have multiple factors and SD is one of them, but crew response management (CRM) and other things might also be involved. Is that how you define that at least one of the causal factors is SD?

A - Mr. Bill Ercoline. That's correct. If one of the checked factors is SD, then it becomes an SD mishap. That's easier said than done, that's the problem. It can get lost in the other causal factors. It boils down to understanding of the problem, and a willingness to recognize that it's SD. A lot of times, if you get into the details of CRM, they may not want to classify it as an SD mishap.

Q - CPT McMullen. For the Air Force - you say that your rates have gone down. Just as a simplistic overview of a number of the cases that we've talked about, it seems that in many cases there was clearly either lack of knowledge, or adherence to standards in terms of what the pilot should or should not have been doing. Have there been stricter means of enforcing those standards or better ways of educating the pilots so they know what their standards are? An example is where SD came about because the pilots violated the standards that they should have been following.

A - Mr. Bill Ercoline. If you follow procedures, more than likely you're not going to become a Class A mishap, not just the regulation procedures, but also flight technique procedures. So there are intentional violations (like disregarding regulations), and then there is the situation where you think you are doing something correctly and the aircraft is not behaving properly (for example, you wish to set 10 degrees nose up to climb out, but because of other things going on, you felt you did it but didn't cross check - that's SD).

A - Lt Col Neubauer. In the USAF there is also slow transition to being smarter about where and when we fly. A "can do" attitude may not be the attitude to have in every case. We're now allowing a lot more people to back out of things that may not be as safe as they think.

Q - Mr. Bill Ramsey. For the Air Force - have you had any accidents from SD due to poor cockpit design; e.g., radios in the wrong place (like the OH-58 transponder).

A - Mr. Bill Ercoline. We had a pilot who misinterpreted HUD symbology after being "head-down" in the cockpit, and rolled the aircraft the wrong way. Another example, but one where the pilot died, so we can't be certain: he was making a turn with his head down in the cockpit, and for some reason the airplane ended up inverted on the ground. In the attitude symbology the blue (of the sky) remained at pitch nose down of greater than 30 degrees. The numbers change but are very hard to read and the color display freezes. So the "picture" of 70-80 degrees nose-low looks the same as about 30 degrees nose-low. In a high workload, you'll miss the numbers. We've always felt that to solve SD, two things have to be done. You have to have good training, both ground and flight; and second, you have to design symbology properly because we're visually dominant.

A proposed SD mishap investigation annex

During the last part of this session, Lt Col Malcolm Braithwaite presented a proposed SD mishap investigation annex.

We have seen the variability of classification of SD accidents between the three safety centers. All speakers have agreed that it would be most useful to standardize classification so that the true size of the problem and a proper comparison can be made, and that controls can be identified to limit the impact of SD in the future. This is one of the thorniest problems in the operational management of SD, and one which has vexed both the Triservice Working Group (TWG) on SD, and Working Party 61 (WP 61) of the Air Standardization Coordination Committee for many years. Even within a service, there is often little correlation between the opinion of operational and aeromedical staff who investigate and report on accidents, and there is certainly a problem between nations.

So, what can we do about it? Rather than suggest a change to nation's and service's classification (which is unlikely to happen), we at both the TWG and WP 61 thought that it would be more reasonable to add to the classification process for mishaps in which SD was considered to be a factor. It has been heard from several speakers that if one doesn't go looking for SD, it won't be found, so we need something to help us.

It would be an advantage if we could devise a deductive algorithm, one that could be followed and get the answer SD at the end. But because SD is so multifaceted, this is a very difficult task. Therefore, the format that has been devised is more of a checklist. It starts by asking the question "could SD be a factor in this mishap?" So, the definition is important, and I hope we've come to a better understanding of that in the last 48 hours. The form has been proposed as an annex for the investigation of mishaps and incidents not leading to mishaps, but exactly who should use it can be discussed following some familiarization with it. While the document is changing, it has been kept as a consecutive list of questions. This is reproduced at appendix E. Once finalized, it will be made into a proper algorithm, or computerized.

Many of the things that we have proposed as important will be recognized, as the annex was originally drawn from Durnford's and my work at USAARL. There are some references to fixed wing aircraft in it because it is designed to cover all types of aircraft.

Attendees at the symposium were then divided into syndicates and practiced completing the proposed annex using examples provided.

Discussion session

The discussion at this session was transcribed from audio tape. Questions are prefixed by "Q," answers by "A," and interjected statements by "S."

Q - MAJ Tom Greig. With reference to the question on type 1 or type 2 SD. If SD is present in an accident, will it ever be anything but type 1?

A - Lt Col Braithwaite. Remember the dynamics of SD. One can start off with an awareness of conflicting inputs of orientation (type 2 SD), and rather than overcoming the conflict, base one's control of the aircraft on the false perception and so lead to an accident. This path to an accident is less frequent than type 1, but is possible.

Q - Mr. Larry Boshiers. I felt this was a useful tool. Could we use the same approach in mission planning (like risk assessment)?

A - Lt Col Hill. The "MEJSA" model that I described does just this.

Q - Dr. Tamara Chelette. I think you should move question 1, "Could SD be a factor in this mishap or incident" to the very end.

A - Lt Col Braithwaite. That's attempting to make the form "deductive."

Q - Dr. Tamara Chelette. Right, the whole form is a sort of thought-channeling process, a decision tree that leads you through a set of decisions. For example, "Were they wrong about the altitude, airspeed or power?," leading to a possible conclusion that they were spatially disoriented. This form asks someone to make that decision "up front" before they have examined any of the other thought processes.

A - Lt Col Braithwaite. The reason that we have this question at the beginning is that I don't believe that this is a proper decision making tree, and the form is not totally deductive. At the moment, it serves as a checklist of information. Even if it is considered that SD is only an incidental factor, this checklist should be completed.

A - Sqn Ldr Maidment. The reason that this question was placed at the beginning is that it is foreseen that this annex would be completed by the flight surgeon at the accident site. He's already going to be completing a very large form and we didn't want to be overloading him with nugatory paperwork if SD is clearly not a factor. Perhaps question 3: "What was the role of SD in this mishap or incident?" should be moved to the end of the form.

A - Mr. Bill Ercoline. I agree. Gather the facts and then make a decision.

Q - Dr. Tamara Chelette. Maybe you could just rephrase question 1: "Was SD clearly NOT a factor in this accident?"

A - Lt Col Braithwaite. Good idea. We'll talk about that at the SD TWG.

Q - Lt Col Hill. Question 5: "How would you classify the SD that played a role in this mishap or incident?" forces me to make a choice. Maybe a more appropriate alternative would be, "Do you think type 1 SD is a contributor?," "Do you think type 2 SD is a contributor?" An example might be where I enter an unrecognized SD condition, and I convert that to type 2 as I bust through the cloud layer and try to take evasive action, but it doesn't happen. I think I could have a case where I have both involved.

A - Lt Col Braithwaite. Thank you. We'll take that point on board.

S - MAJ Keith Steinhurst. I think it's a great idea. The whole point of this forum is to determine whether we're doing enough as flight surgeons to make this issue of SD a little higher for the command to consider. We had a good discussion in our syndicate group over the different attitudes that different people on the board might have about what the crew were doing or not doing when they impacted the ground. For me, this approach is really good. The order of the questions should probably take a back seat to the fact that we're actually trying to do something.

S - Lt Col Braithwaite. Thank you for that very positive comment, Keith.

Q - Unidentified. How do you estimate how long the aircrew were disoriented?

A - Lt Col Braithwaite. Only if you can ask them, or accurately reconstruct the accident.

Q - Unidentified. I think there should be more space for additional comments.

A - Lt Col Braithwaite. I agree. To save trees, the present outline is a skeleton format.

S - Lt Col Braithwaite. Let's try to tie this together. Are we all agreed that this is a good idea? (Ed. response was "yes," with no dissenters). So, do we field it, to whom, and through whom? You are the experts from the safety centers and flight surgeons from the field. Please advise me.

Q - Unidentified. What are you going to do with the information when you've got it?

A - Lt Col Braithwaite. I would suggest feeding the completed forms back to the safety center surgeons. I look to my colleagues to agree or otherwise.

Q - Mr. Bill Ercoline. There's a lot of things that can be done with this. You can go back to the equipment manufacturers and show where there are deficient areas of symbology. There are things to be changed in the cockpit.

A - Lt Col Braithwaite. I completely agree with you, Bill. I said in my introduction that we need to accurately get the number of accidents in which SD is implicated so that we can compare them

with other accidents and then address future operational research, technical controls, and so on. Before that, somebody has got to get the information in the first place. I would suggest that the first point of "collation" is the safety center surgeon. Any objection to that?

Q - Lt Col Mason. If SD is an issue, it shouldn't be hidden in our aeromedical analysis. It should be a finding and a recommendation of the board, perhaps listed that SD is a primary causal factor or contributing factor within the report itself.

A - Lt Col Braithwaite. I quite agree, but as we have seen, if we just rely on the board's report we're not going to have all that other useful information. For example, "Was there an illusion, was there deficiency of visual cues, and what can we do about it?" So all the information that we're collecting needs to be collated and then disseminated in perhaps a similar fashion to the way in which we have been analyzing the accidents long after they have occurred.

Q - Lt Col Mason. One of the problems we're having is that we have very large databases that don't accurately reflect what's going on out there with regard to SD. If this proposed checklist were to end up in the board's final report, then it's going to show up in the database. It won't have the detail, but at least it will indicate that there was an issue.

A - Lt Col Braithwaite. Right, but if we're going to field an annex like this, we need to get the information back from it, and this is my point. Does the investigating flight surgeon complete it? I would suggest so. He would then send the report forward to the safety center surgeon for collation.

Q - Lt Col Mason. Captain Almond, do you find times that the aeromedical analysis (AA) contradicts what is in the actual mishap investigation report (MIR)?

A - Capt Almond. In the book it says that the aeromedical causal factors should be the same as those in the official MIR. That's been my experience in the last 3 years. The AA is just a reflection. It expands and discusses the human factor areas in detail, but the same "who, what, and why" criteria are used. If the flight surgeon can't convince the rest of the board members that SD was a causal factor, then I'm not sure it was.

S - Lt Col Braithwaite. We don't seem to be in a decision-making mood at the moment. Perhaps this is not the correct forum to discuss administrative issues.

S - Lt Col Neubauer. In the USAF, the life sciences report originates in the safety center. We change it and do whatever we want with it. So if this annex were fielded, we would incorporate it into our report format that we send out to all the flight surgeons, and have written into regulation, etc. In our forms, we already have many human factors aspects that are also covered in the proposed annex. A job that certainly falls on me is to try to develop a "shell" over some of the 300 or so human factors that we have listed so that we can say that this "glob" of human factors is indeed SD. In other words, not leave it to the flight surgeon at the scene, but leave it to us as we code it into the database so that it becomes an SD accident.

Q - Lt Col Braithwaite. Are you suggesting that you should be the one to complete the annex?

A - Lt Col Neubauer. My comment about coding was an aside, not talking about the annex itself. No, if we are going to use the annex, the flight surgeon at the scene should complete it, and when it comes back to us it gets put into the computer. I'm also suggesting, that at least in the USAF's realm, instead of just a list of human factors, we need to develop pointers to SD without somebody at the accident saying "This was or was not SD."

Q - Lt Col Braithwaite. That's the USAF's own taxonomy problem?

A - Lt Col Neubauer. Yes.

Q - Mr. Larry Boshiers. I think this is an excellent idea. I would request that, however, you in the military choose to institute this into accident investigation, and however you recover the information, don't keep it to yourselves, as SD is not just a military problem. In the civilian environment, we have more pilots than all of you put together, and we would benefit from any kind of information that you could gain.

A - Lt Col Braithwaite. You say that you might benefit. There is no reason why you should not contribute either.

S - Mr. Larry Boshiers. That's correct. My intent was to get together with Steve Verroneau and show him the annex and get him to contact you.

Q - Mr. Mike Moran. I think that we all agree that the rotary-wing SD issues are unique, regardless of service. My proposal is that the three safety centers pull together with a joint working group to come up with an annex that all three services can live with for investigating rotary-wing mishaps that involve SD. As a trainer, I see three services with three different lexicons looking at the problem from three different points of view. This is part of our problem. If the services can come up with a joint resolution, then I, as a trainer, can help you come up with joint training to train your investigators to look at the problem.

A - Lt Col Braithwaite. Thank you, that is a useful comment which is leading into the final wrap-up. Are there any further comments on the proposed annex at the moment? My personal feeling is that once we have a final version of this annex approved by the three services, then we should field it through safety center surgeons down to the field flight surgeons who will complete it at the next few accidents and then return it to the safety center. Can this be done in parallel to the normal accident investigation procedure? In other words, a sort of "field trial" of the annex. (Ed note. There were assenting remarks from the Navy and Air Force Safety Surgeons, and from one of the Army Safety Center staff on behalf of LTC Murdock). Thank you, unless there are any further comments on the annex, let's try and draw things together. (Ed note. The final discussion is recorded under the next section).

Final discussion

Lt Col Braithwaite made the following remarks before the final discussion.

We've spent a couple of days on SD and I'm sure it's been a long time since this topic was considered by so many in one place. I appreciate all of you coming, and particularly the efforts that our speakers have made to help make this symposium successful. We have agreed that the impact of SD on rotary-wing operations is significant, and that we should do more about it. My brief when I was asked to chair this symposium was to determine what needs doing, how it needs doing, and when we are going to do it. We shouldn't just go back to our units and agree to meet next year without anything happening in the interim. I need your help to find the appropriate direction.

We've talked about training. There is an overall initiative to try and standardize initial entry aeromedical training throughout the services. I suggest that SD training can therefore be covered within the forum of overall aeromedical training. I realize that there are constraints with the good ideas that we may put forward, such as money, manpower, aircraft hours, etc., but I don't feel that should deter us at this stage from what we're trying to do to. The fiscal aspects can be single service issues once we have a triservice agreement and recommendations on the way ahead. How do we go forward? A vehicle does exist for triservice cooperation in SD. This is the TWG which is part of the Triservice Aeromedical Research Panel (TARP). The TWG, to date, has primarily been a means to discuss areas of research so that we minimize overlap and cooperate. However, within the charter of the TWG is the ability for the chairman to set up sub-groups to address a particular problem. There is no reason why other "non-TWG" personnel cannot be co-opted into a sub-group. So, I propose that the TWG should be tasked either by themselves, the TARP, or even the Commander of the Army Safety Center to develop the conclusions that we've come to in this symposium, find the common ground, and make recommendations that can be implemented on a triservice basis. These would include enhancing the awareness of SD to the commanders who make the decisions, training and data collection from mishaps. Do we agree that this is the way forward or would anyone like to suggest an alternative approach? (Ed note. There was no alternative response to this suggestion).

Good, I'm glad we all agree that this is a good idea. Brigadier General Konitzer, the Commander of the Army Safety Center is the most important officer that has been concerned with this symposium. I would like to ask him to forward a memorandum to the aviation brigades and perhaps his opposite number in the Navy and Air Force Safety Centers. The document would summarize the issues raised at the symposium, which issues should be addressed on a triservice basis, and direct the TWG to address the issues and report back to him within a defined time period. That is my proposal. Remember that we are a collective body and that we have been considering the problem of SD together. Does anyone object to this plan of action?

Q - Mr. Bill Ercoline. I think everything you're suggesting, and this symposium, has been excellent. I think most of us have gotten something out of it. I'm just concerned that if you address just rotary-wing issues, we're going to miss a lot of the problems that are still out there.

So I would suggest that if you get that kind of attention, do it now to get it right. We've been underestimating this pilot killer for 70 years.

A - Lt Col Braithwaite. I hear what you say, Bill, and it would be good to catch everything. I think that, at present, I must have personal loyalty and reiterate that the Army's main interest is the helicopter environment. We have got them together on a rotary-wing theme and I wouldn't want to "dilute" the issue to our primary customer. There is no reason why some of the rotary-wing aspects cannot be applied to fixed wing. After all, the accident investigation annex was designed for both types of aircraft. I wouldn't want to make the issues too big so that we can't tackle it within the next 12 months. So, a bite at a time, rotary-wing first, and hopefully the fixed wing aspects will easily follow.

S - LTC Toomey. Most of the training manuals that we use tend to illustrate SD in the fixed wing environment. The perception is that in a helicopter, you are flying low and slow and you can't be disoriented. This symposium has illustrated that this is not the case and hasn't been so for some time. If the TWG were to focus on the rotary-wing problems, it may stimulate some thought from the fixed wing arena, but there's already a great deal of work being done there while there's none here except for the local effort. I think that's another reason to focus on one small area at first.

Q - LTC Richard Carter. Is one of your proposals to use the British Army SD demonstration sortie that you described?

A - Lt Col Braithwaite. At present, I am just assessing the usefulness of this sortie for the U.S. Army. I hope it will become a recommendation to improve aircrew aeromedical training in SD.

Q - LTC Carter. Who is it that sets standards for qualification? Our training center meets Army standards for IPs. I know of no requirement for IPs to have any in-flight SD training such as you are suggesting. I think it is reasonable to propose that they have it, but I am not sure who makes the written regulations to say that an IP course must include a certain standard to be met.

A - Lt Col Braithwaite. Would you like to take the first task of the TWG subgroup, and find out and let me know, and then we can address that should it become an agreed recommendation with action to that particular office.

A - LTC Carter. We can do that.

There being no further comments from the floor, Lt Col Braithwaite concluded with the following remarks.

That's all I have to say. Thank you to our speakers and to you for attending. I hope that you have gotten a lot out of the symposium. We will publish the proceedings of this symposium and produce a memorandum to the Commander of the Army Safety Center. Remember though, that

there is no reason why you shouldn't take what you have gained from the last 2 days straight back to your units and start applying the principles in your own local fashion.

Closing address

The symposium was closed by an address from CW4 (ret) Michael Novosel, Congressional Medal of Honor winner. The text is not recorded in these proceedings.

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Appendix B: Introductory remarks about speakers

Lieutenant Colonel Ed Murdock

Lieutenant Colonel Ed Murdock is a former Air Defense officer who the gained an M.D. from the Uniformed Services University in 1981. After internship, he qualified as an Army flight surgeon and later received a master of public health degree from Johns Hopkins University. He then became board certified in aerospace medicine in 1992. He is once again the Command Surgeon for the U.S. Army Safety Center. During his previous tour in this post, he researched SD and was one of the key presenters at the Pensacola conference in 1993. He has also presented his work on SD at Aerospace Medical Association meetings.

Lieutenant Colonel Malcolm Braithwaite

Lieutenant Colonel Malcolm Braithwaite is a consultant in Aviation and Occupational Medicine. In common with all British Army flight surgeons, he is also a rated aviator. He has specialized in aviation medicine since 1981 and held operational and research posts in the United Kingdom and Germany. His responsibilities have included advice on many aviation medicine operational matters. Since May 1995, he has been the U.K. Exchange Flight Surgeon at USAARL, where he runs the SD team.

Captain Myron Almond

Captain Myron Almond originally majored in electrical engineering at the University of Arkansas and then served as a Naval officer between 1971-1974. After leaving the Navy in 1974, he earned his master's degree in mechanical engineering and completed pre-medical work before returning to the Navy for medical school training at the Uniformed Services University of the Health Sciences and received his doctor in medicine in 1981. He entered flight surgeon training at Pensacola in 1983, and in 1988 became a specialist in aerospace medicine. In 1994, he was transferred to the Naval Safety Center where he is presently the head of the Aeromedical Division.

Commander Rick Mason

Commander Rick Mason was commissioned into the Medical Service Corps in 1982 and after receiving his wings, was designated as a Naval aerospace physiologist at the Naval Aerospace Medical Institute, Pensacola. He has had a great deal of experience as an aerospace physiologist and aeromedical safety officer, and now holds the exulted post of Wing Aeromedical Safety Officer with the Third Marine Aircraft Wing, Marine Forces Pacific at El Toro, California. His duties include overseeing and managing the Wing's aeromedical safety programs and introducing new or modified aviation life support equipment to aviation personnel. His expertise in SD is particularly illustrated by the fact that he has served as an aircraft mishap board member for 5 mishaps that involved SD and was the endorsing officer for 11 additional SD mishap investigation reports.

Lieutenant Colonel Jay Johnson

Lieutenant Colonel Jay Johnson is the Helicopter Flight Safety Officer at the Air Force Safety Center and is responsible for all aspects of safety - prevention, mishap investigation, data analysis, etc. He was commissioned into the Air Force in 1973 and after flying fixed wing, he now has an excellent helicopter and aviator training background including nearly 2000 hours on the H-3, mainly flying combat rescue. His previous appointments have included responsibility for writing undergraduate pilot syllabus and, as Chief of Standardization and Training for combat helicopters, he coordinated all the cross-functional helicopter issues including budgets, plans and programs, personnel, maintenance, safety and operations.

Lieutenant Colonel Jeffrey Hill

Lieutenant Colonel Jeffrey Hill is an Air Force aerospace physiologist with 14 years experience. He has been involved in testing and evaluating various pieces of medical and life support equipment, as well as running physiological training for combat crews in many parts of the world. He is now the staff physiologist at the Air Force Special Operations Command at Hurlburt Field, Florida. This is the office of prime responsibility for the Air Force helicopter physiological training.

Captain Greg Thompson

Captain Greg Thompson is Chief of the Flight Physiology Branch at USASAM and responsible for the training of all who pass through USASAM. During his distinguished service career, he has gained a baccalaureate in aeronautics and a masters in business administration, as well as being an experienced UH-1, OH-58 and AH-1 pilot.

Squadron Leader Graeme Maidment

Squadron Leader Graeme Maidment received his medical degree from the University of Oxford, England. He was commissioned into the Royal Air Force and after a year as Medical Officer at two Royal Air Force bases joined the specialty of aviation medicine at the former RAF Institute of Aviation Medicine, Farnborough. During his time at Farnborough, he gained expertise in the thermal aspects of aviation medicine, particularly cold physiology and survival medicine. He holds the diploma in aviation medicine, and was awarded a Ph.D. from the University of London for his thesis on 'Effects of Regional Cooling on Thermal Balance in Humans.' He is currently a senior specialist in aviation medicine, and is working as an exchange officer to the United States Air Force at the Armstrong Laboratory at Brooks AFB in the Spatial Disorientation Counter-Measures Task Group. In addition to providing specialist medical input, he is the principal investigator for the research conducted using the advanced spatial disorientation demonstrator.

Captain Jonathan Clark

Captain Jonathan Clark is a board certified neurologist and aerospace medicine specialist with over 20 years of military experience, and 9 years in operational medicine and spatial orientation research. He received his doctor of medicine from the Uniformed Services University of the Health Sciences in 1980, and masters of public health from the University of Alabama, Birmingham. He has had many interesting assignments. To name but two - He was a DOD space shuttle support flight surgeon and covered the first launch of Endeavor in 1991 and he was also the first Head of the Aeromedical Department at the prestigious Marine Aviation Weapons and Tactics Squadron One, where he worked on spatial disorientation, night vision goggle human factors, and sustained flight operations. He is currently the Head, Spatial Orientation Systems Department at the Naval Aerospace Medical Research Laboratory (NAMRL), Pensacola, where he is also the principal investigator on the Neuro-otologic Assessment Program.

Dr. Anil Raj

Dr. Anil Raj is an assistant research professor for the Spatial Orientation Systems Department at NAMRL. After receiving his M.D. from the University of Michigan School of Medicine in 1990, his interests in aerospace medicine research led him to Pensacola following a two year fellowship as a National Research Council Resident Research Associate at the NASA-Johnson Space Center, Houston. His interests focus around the human physiological and psychological responses to accelerative forces, particularly how changes in acceleration affect the sense of spatial orientation. Among his many tasks, he has been a driving force in the development, test and evaluation of vibrotactile vests to improve situational awareness.

Dr. Tamara Chelette

Dr. Tamara Chelette is a biomedical engineer with the Combined Stress Branch of the Armstrong Laboratory at Wright Paterson AFB, Dayton, Ohio. In 1994, she received her Ph.D. in biomedical sciences from Wright State University and was selected as an associate fellow of the Aerospace Medical Association. She conducts basic and applied research in the area of human spatial perception in the unusual environments found in highly maneuverable aircraft, and also teaches classes in vestibular function and human performance in extreme environments. She has served as the principal investigator on several major research projects on the dynamic environment simulator, a 9 G centrifuge and closed loop simulator.

Mr. Bill Ercoline

Mr. Bill Ercoline is a retired Air Force lieutenant colonel command pilot with over 3,500 hours flight experience, including 2,000 instructor pilot hours. He was a consultant for Air Force Mishap Investigation Boards of spatial disorientation aircraft accidents and has conducted extensive research into the history of instrument flight. He is currently on contract to the Air Force at Brooks AFB, San Antonio, with Systems Research Laboratory where, among many tasks, he supports the Spatial Disorientation Countermeasures Task Group. His current work includes studies of the visual, vestibular, and auditory sensory systems and their interactions and relationships to flight. Specifically, his research deals with the design and application of displays and display symbology to maintain spatial orientation in military aircraft; training methods to prevent the causes of SD; and a knowledge base to understand the physiology of spatial orientation.

Appendix C: Preprint: The British Army Air Corps in-flight SDdemonstration sortie

by Malcolm G Braithwaite MB. ChB. DRCOG. DAv Med. DIH. MFOM

Introduction

Demonstration of some of the illusions of spatial disorientation (SD) and the limitations of the orientational senses during ground-based training is a vital part of the proper education of aviators. Most student pilots are given instruction during their flight training on how to overcome the effects of SD, but few air forces provide a specific SD demonstration sortie to reinforce the knowledge gained during ground-based training.

There is a distinct difference between in-flight demonstration of SD, and training to overcome the problem once it has occurred. A demonstration of SD consists of reinforcement of the limitations of the orientation senses in flight and the enhancement of aircrew awareness to potentially disorientating situations. SD training, on the other hand, consists of a series of flight procedures to cope with disorientating circumstances and illusions (e.g., recovery from unusual attitudes during instrument flying). SD training is clearly the responsibility of the flight instructor in both simulator and actual flying sorties, while the demonstration of physiological limitations is best conducted by the flight surgeon pilot who, having performed the ground-based training, is on-hand to explain the mechanics of SD.

A specific British Army spatial disorientation sortie was developed and has been conducted since 1982. Although the U.S. Air Force used to fly a similar sortie, no other nations or service is known to currently enhance the awareness of aircrew in their physiological limitations in this way (3). The aim of the SD demonstration sortie is to reinforce, in a real environment, the ground training received in SD and consequently increase the awareness of trainee pilots. The objective has been to provide aircrew with an initial SD demonstration sortie and a refresher every 4 years. This has been achieved in the main since it has become a mandatory requirement of aircrew continuation training. This paper describes the conduct of the sortie and discusses the operational and cost benefits.

Description of the SD demonstration sortie

The sortie is flown by a pilot-physician (flight surgeon) in the Gazelle AH1 helicopter (SA 341). Three students can be flown on each sortie, one in the copilot's seat and two in the rear passenger seats. It can be completed in about 25 to 30 minutes flight time and so 12 students can receive the demonstration in 2 hours. The sortie was originally adapted from those described in Benson (1) and has since been modified from the description provided by Edgington and Box (5).

Students typically have had about 100 hours basic fixed wing and basic helicopter experience

and will fly the sortie before they start rotary-wing instrument flight training. They will have completed the classroom aviation medicine and disorientation training a few weeks prior to the sortie.

General reassurance is given that no violent maneuvers will be flown, and that only one student will have his or her eyes shut at any one time for no more than a minute or so. During each demonstration, the subject student gives a running commentary of his/her perception of orientation with particular reference to pressure altitude, heading and airspeed. Primarily for flight safety reasons, the sortie is best flown in good visual meteorological conditions (VMC), but since it is difficult to completely prevent transmission of light to the eyes, bright sunlight is best avoided. In order to save time, the sortie is conducted close to the base airfield, but an area of low aviation activity is chosen for safety. The observing students are also instructed to assist with aircraft lookout.

During the transit to the exercise area, the use of the special senses in orientation is only briefly reviewed, as initial students have received classroom instruction a few weeks prior to the sortie, and refresher students a lecture on the same day as the sortie. The overwhelming contribution of vision to orientation is stressed together with the fact that SD is primarily a problem associated with poor external visual conditions, thus emphasizing why the students will be deprived of their vision during the exercises.

The specific maneuvers have been chosen on the basis that they are simple to perform are easily repeatable and have operational relevance to the most commonly experienced types and degrees of SD. At the commencement of each maneuver, the subject student is told to sit free of the controls and airframe structures other than the seat, note the aircraft's initial flight parameters and then to close his or her eyes and give a running commentary as described above. The other students are asked to observe but not comment until after the maneuver. Each student experiences at least one exercise in each of the forward flight and hover groups.

<u>Forward flight</u>

Exercise 1

Straight and level flight is established at 100 knots. After 10 seconds, a gently increasing (supra-threshold) roll to 30° angle of bank is commenced while maintaining airspeed and pressure altitude. This is stabilized and, on completion of a 360° turn, the aircraft is rolled wings level again at a supra-threshold rate. The onset of the roll is normally detected, but as the semicircular canal response decays, a false sensation of a return to straight and level flight is perceived. As the roll to level flight is made, a sensation of turning in the opposite direction is perceived. The student is told to open his or her eyes once he considers that he or she is again straight and level. The observing students are asked to tell the subject what actually happened and all are asked for their comments. The fight surgeon will then remind the students of the physiology of semicircular canal performance.

Exercise 2

Straight and level flight is established at 100 knots and one of the other students is asked to close his or her eyes. The aircraft is flown with no alteration of height, heading, or airspeed. Because of small aircraft movements from turbulence and the aerodynamic response of the helicopter which stimulate the kinaestheic and/or the vestibular apparatus above threshold, all students perceive climb, descents, or turns in unpredictable and varying amounts. The erroneous sensations produced by brief stimulation of the kinaestheic receptors and vestibular apparatus is discussed.

Exercise 3

Straight and level flight is established at 100 knots into wind, and once the subject has closed his or her eyes, the helicopter is slowed within 30-40 seconds to a free air hover with no change of heading or height. Both the deceleration and the nose-up pitch associated with the attitude change when slowing the aircraft convinces the student that a climb is taking place. In addition, a turn is often falsely perceived when balance variations are made to keep straight. The somatogravic illusion is discussed.

Exercise 4

This maneuver is best conducted from 500 ft above ground level. Straight and level flight is established at 100 knots and the student closes his or her eyes. A sub-threshold descending turn is commenced as gently as possible. Within 30 seconds in the Gazelle, it is possible to lose 500 ft in height and turn through 180°. The student, remembering the second demonstration, usually states that he or she is straight and level. When the aircraft is established in low level flight, the student is asked to report his or her heading and height and airspeed and then open his or her eyes. This demonstration forcibly and convincingly demonstrates a type 1 orientation error, due to the proximity of the ground.

Hover

The helicopter has a unique ability to accelerate about as well as along orthogonal axes, thus the final series of demonstrations starts from a 5 or 6 foot hover. For this series of exercises, it is most important to check for hazards; the terrain surroundings should be familiar and a good lookout maintained during clearing turns between each exercise. In turn, the three students are exposed to a variety of linear and rotational movements whilst maintaining hover height. The flight surgeon keeps prompting the subject for a running commentary (to occupy channels of attention) and so exacerbate the onset of SD. Most aircrew are able to maintain their orientation for 10 to 15 seconds before losing it. Within these exercises it is possible to "hide" various maneuvers so that when the student opens his or her eyes, a dramatic end point is evident:

- a towering vertical climb to 200-300 ft.

- climbing backwards at 10-15 knots.

- landing without the student realizing it.

- a gentle transition to forward flight.

These exercises have a most educational effect upon the observing students and are discussed in the context of snow, sand, and night operations.

Additional exercises

The exercises described above are the recommended minimum. Should time permit, and particularly for refresher training, variations of these exercises and additional ones can be performed:

- Straight and level flight is established at 100 knots, the eyes are closed, and the aircraft dived to a 20° nose down attitude. A steady pull up to 30° nose up is then made with a gentle bunt recovery. Most students perceive a continuing full loop; some experience a barrel roll sensation.

- The reverse of slowing down to a free air hover can be flown; i.e., from a slow speed to maximum cruise speed. Diving sensations are usually perceived.

- From a free-air hover into wind, the aircraft is pitched nose down to approximately 50°. This demonstration is visually stimulating to the observers, but the angle of pitch down is generally "under-perceived" by the subject.

- In steep turns each student in turn is invited to perform rapid head movements in pitch or yaw to experience the coriolis phenomenon.

Debriefing

On the return flight to the base airfield, the sortie is discussed with particular reference to the significance of sub-threshold maneuvers and erroneous sensory information cues. The students are reassured that they are all physiologically normal but just not "designed" for flight. It is stressed that the aim of the sortie has been to provide them with an idea of the limitations of their own physiology in the environment in which they operate and the phases of flight commonly associated with SD. Similarly, they must realize that they have not been trained to overcome the effects of SD. That is the responsibility of their flight instructors to address during later training in the recovery actions from unusual attitudes and procedures upon inadvertent entry into IMC. They are advised that the best

that they can do individually with respect to SD, is to achieve and retain currency and competency at instrument flying.

Benefits of the sortie

Operational benefits

In order to estimate the benefit of this sortie on British Army Air Corps operations, the non-hostile SD flying accidents (i.e., excluding ground-handling mishaps) were compared between the periods before (1971-1982) (7), and since (1983-1993) (2) the introduction of the sortie. The SD accident rates were 2.04 accidents per 100,000 flying hours and 0.57 accidents per 100,000 flying hours, respectively. Using a Poisson regression analysis (6) the Likelihood Ratio in the Type 3 analysis revealed a significant difference between both the period (Chisquare (df=1) = 5.8563; p = 0.0155), and classification of accident (Chisquare (df=1) = 73.9731; p = 0.0001). This was interpreted to demonstrate a period effect of a highly significant reduction in the SD accidents rates since the sortie has been introduced.

There are confounding factors in this analysis. Some factors will have tended to reduce the orientation error accident rate; e.g., the introduction to service of aircraft with automatic flight control systems and stability augmentation in the late 1970s; the installation of additional aircraft flight instruments (e.g., radar altimeters) in the early 1980s; the phasing out of predominantly single pilot operations in the mid 1980s and subsequent introduction of two qualified pilot crews for most sorties in the late 1980s; and a reclassification of the accidents to exclude the lesser damaged airframe in 1991. A counterbalancing factor which has tended to increase the orientation error accident rate is the much greater use of night vision goggles since the mid 1980s. These devices, while enhancing external visual cues in the dark, do have considerable limitations in the perception of orientation. Notwithstanding these arguments, it is reasonable to assert that the SD demonstration sortie has contributed to reducing the accident rate in which SD is involved. This is most encouraging, especially as the military flying task is becoming more complex and now leaves little room for error from a physiological limitation such as SD.

Pilot acceptance

The SD demonstration sortie has gained wide acceptance by Army pilots. It is extremely rare for aircrew not to misperceive their orientation during the maneuvers. In a survey conducted by Durnford (4), 79 percent of 338 aircrew considered the sortie to be beneficial, 19 percent were indifferent and only 1 percent considered it harmful! This finding confirms the subjective value of this additional aeromedical training.

Cost benefit

From 1982 until September 1995, 1069 initial and 597 refresher students have flown on this sortie. One hundred and eighty Gazelle helicopter flight hours have been logged on initial training and 130 hours on refresher training. Using 1996 military operating costs, this represents a total cost over nearly 14 years of $252,000 US. This figure is less than one tenth of the replacement cost of the least expensive in-service British Army helicopter, and it would take many years of training at this cost to justify the purchase of a modern electro-mechanical demonstrator.

Conclusion

The SD demonstration sortie has been a most successful enhancement to the aeromedical training of British Army pilots. Both operational and cost benefits are apparent, and aircrew fully appreciate the value of the demonstration. There is therefore strong justification for the continuance of the sortie. Furthermore, similar instruction to that described in this paper could be readily adopted by other services. The author is presently conducting an acceptability assessment of this sortie in the U.S. Army and is most willing to communicate directly with interested parties.

Disclaimer

The opinions and conclusions above are those of the author and should not be construed as reflecting the policy of the British Army or United States Department of Defense.

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Appendix D: U.S. Navy SD syllabus

1. INTRODUCTION

SPATIAL DISORIENTATION DEFINITION False Perception of Position or Attitude Relative To The Plane of Reference

SPATIAL DISORIENTATION CLASSIFICATION
- Type I - Unrecognized Disorientation
- Type II - Recognized Disorientation
- Type III - Recognized Disorientation, With Sense of Inability To Control Aircraft
  - Giant Hand Phenomenon - False Perception That Aircraft is Actively Resisting Efforts At Control
  - 1) Inappropriate Focus of Attention
  - 2) Degradation of Psychomotor Skills To Primitive Orientation Reflexes
  - 3) Final Stage- Frozen on The Controls

The single most important cause of spatial disorientation is the absent or inadequate visual reference

II. IMPACT OF SPATIAL DISORIENTATION

NAVAL SAFETY CENTER MISHAP STATISTICS 1980-1990

GLOC 4 Class A Mishaps
- 28 Physiologic Episodes

SD 122 Mishaps
- 112 Class A Mishaps
- 2 Class B. 8 Class C
- 25 Physiologic Episodes

SD Mishap Causal Factor
- 63 Possible
- 19 Probable
- 40 Definite

SPATIAL DISORIENTATION MISHAPS 1980-1990
NAVAL SAFETY CENTER STATISTICS

SD Mishaps - Phase of Flight

Takeoff	5
In-flight	22
Landing	13

SD Mishaps - Time of Flight

Day	20
Night	20

SD Mishaps - Topography

Over Water	23
Over Land	17

SD Mishaps - 32 Aircraft

Helicopters	11
Fighters	9
Attack	6
Training	6

SD Mishaps - 38 Lives Lost

NAVAL CLASS A MISHAP RATES IN OPERATION DESERT SHIELD AND DESERT STORM

Pre-deployment Mishap Rate (1/90-8/1/90)	3.1
Desert Shield Mishap Rate (8/2/90-1/15/91)	2.63
Desert Storm Mishap Rate (1/16/91-3/1/91)	4.77

Mishap Rate = Class A Mishaps Per 100,000 Flight Hours

IMPACT OF SD IN OPERATION DESERT SHIELD/ DESERT STORM

Losses due to Spatial Disorientation (SD)
- 16 Fatalities
- 2 Fixed Wing Aircraft
- 7 Rotary Wing Aircraft

Losses due to Direct Enemy Action (DEA)
- 11 Fixed Wing Aircraft
- 8 Fatalities

SD MISHAPS OPERATION DESERT SHIELD/ DESERT STORM

Topography
- 4 over water
- 5 over land

Phase of flight
- Takeoff (1 CH-46, 1 AH-1W (Class B))
- In-flight (3 UH-1N, 1 AH-1J, 1 CH-46)
- Approach (1 F/A-18, 1 AV-8B)

Time of Day
- 8 occurred at night
  - 6 on Night Vision Devices
    - 5 on Night Vision Goggles (NVG)
    - 1 on Forward Looking Infrared (FLIR)
- 1 occurred in day during instrument conditions

Night Vision Devices
- 5 Night Vision Goggles
  - 3 in high light level (> .0022 LUX)
  - 2 in low light level (< .0022 LUX)
- 1 Navigation FLIR (No moon illumination)

Tactical considerations
- 7 involved formation flights (all at night)
  - 5 of these were wingman
  - 2 involved midair collision

Visual Factors
- Brownout (2 Takeoff)
- Obscured/ Distorted horizon (1 Approach)
- Faulty closure judgment (1 wingman hit lead during formation)
- Faulty height estimation (4 inadvertent flight into terrain)

Contributing factors
- Fatigue (2 UH-1 N. 1 CH-46)
- Inexperience (1 F/A-18 (FLIR))
- System Failure (1 AV-8B (INS failure))

III. NEUROLOGY OF SPATIAL ORIENTATION SYSTEMS

ORIENTATION - sense of awareness of where body is in space
often automatic/ sub-consciousness
requires accurate sensory input and perceptual response

EQUILIBRIUM - alignment of body center of mass with gravity and support structures

ORIENTATION AND EQUILIBRIUM
Requires Integration of Information Alternatives:
1) Visual System
2) Vestibular System
3) Proprioceptive t (Somatosensory) System
4) Auditory System
5) Efference Copy- Intended Motor Commands

PERCEPTUAL INTEGRATION AND PRIORITIZATION
Sensitivity: Visual > Proprioceptive > Vestibular
CNS sets gain and priority of sensory system inputs
Under sensory conflict inaccurate information is ignored
Vestibular system acts as internal orientation reference, confirming visual and somatosensory inputs

VISUAL DOMINANCE
concept of primacy of vision - ability to use spatial orientation cues from visual environment despite strong vestibular cues, (most important cause of pilot disorientation is inadequate visual reference) disorientation more likely to be due to subtle perceptual inconsistency or insensitivity than overwhelming vestibular response

VESTIBULAR SUPPRESSION
active process of visually overriding undesirable vestibular sensations

VESTIBULAR ENHANCEMENT
increase in perceptual and motor responsiveness to vestibular stimulation resulting in heightened vestibular reflexes and perception causes:
1) lack or underestimate of vestibular response - stimulus novelty
2) change in vestibular gain, set by vestibular neurons
3) attempt to fill orientation information void due to lack or absence of visual information

VISUAL ORIENTATION SYSTEMS

1. Focal Visual System - Central Vision
    - Concerned With "What?"
    - High Spatial Resolution
    - Object Recognition
    - Orient Object Relative To Stable Self
    - Monocular Cues
        - 1) Size Constancy
        - 2) Shape Constancy
        - 3) Motion Parallax
        - 4) Interposition
        - 5) Texture Gradient
        - 6) Linear Perspective
        - 7) Illumination Perspective
        - 8) Aerial Perspective
    - Binocular Cues
        - 1) Stereopsis (disparity individual retinal image, distance estimate accurate to 200 meters)
        - 2) Vergence (convergence of eyes at close distance, accurate 6 meters)
        - 3) Accommodation (change in lens shape to maintain image focus, accurate to 6 meters)

2. Ambient Visual System
    - Peripheral Vision
    - Concerned With "Where"
    - Low Spatial Resolution
    - Spatial Localization And Orientation
    - Orient Stable Environment To Self
    - Motion Cues generates relative visual motion perception
        - Self Motion (Subject)
        - Object motion
            - more sensitive
            - when cue conflict, object motion predominates
        - Surround Motion

VESTIBULAR ORIENTATION SYSTEM

OTOLITH ORGANS
- Detect Linear Motion And Direction of Gravity
- Otoconia (Stones) Resting on Sensory Hair Cells
- Otoconia (Otoliths) - Stones 3 X Density of Endolymph
- Utricle- Horizontal Plane
- Saccule- Vertical Plane, Constantly Exposed To Gravity
- Kinocilia Arranged Along Central Line of Reflection

SEMICIRCULAR CANALS

Angular Motion Detectors

Similar Specific Gravity of Cupula And Endolymph

Detection Thresholds for Angular Acceleration: Range from 0.1 - 2.0 degrees per second (at 0.1 - 2.0 Hz) in natural movements, when the head is tilted from upright, the semicircular canals and otoliths always provide synergistic signals

SOMATOSENSORY (PROPRIOCEPTIVE) SYSTEM

Muscle Spindles

Joint Proprioceptors

Cutaneous Exteroceptors

IV. SPATIAL DISORIENTATION ILLUSIONS

VISUAL ILLUSIONS

Absent visual cues

loss of visual reference leading to spatial disorientation

Whiteout (blowing snow)

Atmospheric Pollution

Brown Out (blowing sand or dust)

Flight into Box Canyon (well lit terrain to dark shadow)

Erroneous visual cues

Faulty Altitude Perception

Errors during approach to landing inadvertent descent into terrain (controlled flight into terrain)

Size/ Shape Constancy

Runway Slope

Terrain Slope

Runway Width

Approach Terrain Composition

Approach Fog/ Haze

Asymmetric Runway Lights

Black Hole Approach

Faulty Attitude Perception

False Horizon, leading to error in attitude, usually in the roll plane

- Lean on The Sun Illusion (during flight with low sun angle and no terrestrial references, pilot tries to fly with the sun on the top)
- Sloping Cloud Bank Illusion
- Line of lights during night flight
- Very High Altitude Flight (high altitude interceptor or reconnaissance aircraft, the horizon is lower, giving sense of pitch up

Lack of Motion Perception

False Motion Perception

Vection Illusion false sense of movement of see due to movement of visual imagery Circular (Angular)Vection (sense of rotation if rotating beacon left on while in heavy clouds, or if Ground Handler or Taxi Director moves at night while helicopter in a hover) Linear Vection (sense of sudden change of closure with another aircraft or movement with change in moving visual scene or optical flow)

Flicker Vertigo (sunlight through rotor blades or flashing strobe light while flying in clouds, creates vection illusion, headache, and myoclonic activity in susceptible individuals)

Autokinetic Illusion

Object Fixation (attention to external visual reference with neglect of other information from instruments)

Break Away or Break off Phenomenon (sudden loss of point of reference, perception of being outside aircraft)

Visual Illusions unique to Rotary Wing Operations

- Waterfall Illusion (during over water hover, water particles in rotor wash create illusion of rising)
- Wave Drift Illusion (during over water hover, waves blowing out forward create illusion of drift backward)
- Crater Illusion - (landing on Night Vision Devices using infrared Searchlight appears like landing in a hole or crater)

VESTIBULAR ILLUSIONS

Leans : Pilot in instrument conditions finds he feels upright if he flies with head at angle, leaning into canopy. The Leans is the most common SD event, experienced by virtually all pilots at some time in their career during instrument flight. This illusion is caused by a slow roll or dip of the wings at a rate of c 3 deg/sec below threshold of detection by the vestibular apparatus, usually when the pilot is attending to another task. When the pilot looks back at his instruments and sees a substantial bank angle (20 deg) the pilot tries to straighten out quickly, then perceives to be in a banked turn in opposite direction, and tries to lean his head to correct for this sensation.

Somatogyral illusion: Pilot in aircraft inadvertently enters a spin or spiral, making several rapid turns in deprived of external visual reference to ground, (IMC). After initial recovery pilot will reenter the spin/spiral in the opposite direction. Illusion due to sensation of turning in the opposite direction after a deceleration from prolonged steady turn, due to inability of semicircular canals to register a prolonged angular rotation.

Somatogyral Illusion Examples: Graveyard Spin, Graveyard Spiral

Oculogyral illusion : Pilot in aircraft making several rapid turns experiences false sensation of movement of a head fixed visualized object initially in the opposite direction, then as turn persists, appears to move in same direction. Probably driven by the vestibular apparatus which drives the eyes opposite to the direction of rotation.

Coriolis Illusion : Coriolis illusion (cross coupling effect) - Pilot in aircraft making several turns makes head tilt to look at other area then experiences false sensation of tumbling (Somatogyral Illusion), or movement of visualized objects (Oculogyral illusion). The Coriolis illusion occurs when the semicircular fluid in one canal reaches constant angular velocity has been and has stopped detecting rotation, then second canal senses rotation when the head is titled. The mismatch in canal sensation causes conflicting inputs to brain, results in a perception of motion in a plane in which no motion is being experienced.

Somatogravic illusions : False perception of upright (local vertical) sensation from resultant vector from linear acceleration and gravity.

Types of Somatogravic Illusions

Catapult Pitch up - False sensation of nose pitch up on sudden acceleration (+Gx) after cat-shot during reduced visual cues, results in incorrect response by pilot of pushing stick forward and impacting water

Hover Stop to vertical landing (Harrier and V/STOL) False sensation of nose pitch down when decelerating to hover during reduced visual cues, results in incorrect response of pulling stick back, and increasing pitch down sensation, leading to pilot induced oscillation

Inversion Illusion - False sensation of excessive pitch up or sudden upside down position occurring after a sudden level off after a climb, pushover or bunt (0 or - Gz) while in instrument conditions or at night. The severe disorientation may result in adverse control inputs and aerodynamic breakup if not recognized

G Excess Illusion

Under +Gz loading, pilot experiences pitch up tilt, and compensates with less back stick pressure, resulting in loss of altitude

Oculogravic illusion - under + Gz (upward), the eyes are driven downward, and the visual scene appears to migrate upward, the opposite effect occurs when the individual accelerates downward. This can be seen in high G maneuvers and turbulence (updrafts and downdrafts).

Oculogravic Illusion Example: Elevator Illusion

Other vestibular Illusions

Giant Hand Phenomenon - Overwhelming spatial disorientation with erroneous sensory motor control response leading to pilot induced oscillations and deteriorating aircraft control, with the pilot experiencing the false perception that the aircraft is actively resisting efforts at control

Alternobaric (pressure) Vertigo - vertigo from vestibular stimulation from asymmetric pressure differential in middle ear while changing altitudes, usually associated with upper respiratory infection and Eustachian tube dysfunction

V. OPERATIONAL ASPECTS OF SPATIAL DISORIENTATION

SPATIAL DISORIENTATION IN ROTARY-WING DESERT OPERATIONS

- Difficulty of altitude estimation
- Unanticipated loss of visual reference
- Obscured or distorted horizon
- Inadvertent descent to acquire visual cues
- Tendency to increase airspeed over flat terrain
- Obstacle recognition
- Desert Terrain Considerations
    - Scrub Desert Terrain
        - Flat To Uneven Profile
        - Sparse To Medium Vegetation - Bushes, Small Trees
        - Visual Cues - Vegetation Vehicle Tracks, Pipelines
    - Dry Lake Bed Desert Terrain
        - Very Flat Profile
        - Dark Hard Crust Sand
        - Visual Cues - Vehicle Tracks, Surface Cracks
    - Sand Dune Desert Terrain
        - Rolling Uneven Profile, Light To Medium Colored Sand
        - Dunes Are Convex Windward, Concave Leeward
        - Visual Cues - Occasionally See Vehicle Tracks, Wind Ripples.
    - Dangerous terrain transitions
        - Dark To Light Sand
        - Scrub Desert To Dry Lake or Dunes

SPATIAL DISORIENTATION PREVENTIVE MEASURES

Keep Aircraft Trimmed up
Cockpit Crew Coordination
Aircrew Scanning - Obstacles, Dust Cloud
Radar Altimeter Callout
Spatial Disorientation Hazard Maps (Terrain Transition Zones, Brown Out Potential, Obstacles, AAA Threat)
Maneuver Around SD hazard zones rather Than Over Them
Anticipate SD during approach and landing (Helicopters can do running landing to avoid brownout)
Brief Spatial Disorientation Avoidance Procedures
Brief Inadvertent IMC Procedures
Brief Emergency Procedures in Disorientation Prone Settings
Recognition of Disorientation By Pilot on Controls (POC)
Pilot on Controls (POC) - Primarily Scans Outside Aircraft
Pilot Not on Controls (PNOC) - Primarily Scans Flight Instruments
Pilot Not on Controls (PNOC) Updates POC on Airspeed, Altitude, System Status
Pilot Not on Controls (PNOC) Ready To Assume Controls

OVERCOMING SPATIAL DISORIENTATION

- Transition To Basic Instruments
- Options:
  - Go Lower And Slower -
    - Acquires Visual Cues
    - Increases Time For Reaction
    - Reduces Obstacle Clearance
  - Climb Out
    - Level Climb Increasing Airspeed
    - Attempt To Get VFR on Top
    - Increases Obstacle Avoidance
    - Increases AAA Threat
    - Reduces Visual References
- If Pilot on Controls Gets Disabling SD, Ensure Positive Change of Controls To Copilot
- establish visual reference(helicopter crew can drop chem light on ground)
- all aircrew scan outside for visual cues
- Remain Calm, establish crew coordination and duties

FACTORS TO BE CONSIDERED IN THE INVESTIGATION OF THE SPATIAL DISORIENTATION MISHAP

ENVIRONMENTAL FACTORS
- IMC Conditions
- Visual Obscuration (smoke/ fog)
- turbulence
- VFR - IFR Transition
- Suspended droplets on windscreen

MISSION FACTORS
- Airspeed
- Altitude (such as High Altitude
- Flight Profile
  - Prolonged Acceleration/ Deceleration
  - Rapid Attitude Changes
  - Subthreshold Attitude Changes
  - Constantly changing profile (Evasive maneuvers to avoid enemy defenses)
- Formation Flight
- Night Vision Devices (NVG, FLIR)

ILLUMINATION FACTORS
- Twilight Transition
- Illumination Level
- Moon Position
- Shadows
- Sunrise/ Sunset
- Light Contamination
  - Cultural Light Sources
  - Point Light Sources
  - Tactical light (flares, strobes, ordinance)

TERRAIN FACTORS
- Terrain Type (Profile, Obstacles)
- Terrain Transition
  - Changes in Color, Contrast, Texture, or Visual Cues
  - Transitions From High To Low Contrast Are Most Difficult (Lose Visual Cues)
- Featureless terrain (inability to judge altitude, with controlled flight into terrain (CFIT)
- Crossing Ridge Line or escarpment (Break off Phenomenon) -

AIRCRAFT FACTORS

- Instrument Visibility/ Placement
- NVG Compatible Cockpit Lighting
- NVG compatible windshield
- Visual Profile from Cockpit
- Aircraft Performance Characteristics
- Control Surface Position/ Feedback
- Light Reflection off windscreen

AIRCREW FACTORS

- Flight Experience (in aircraft type, IFR, NVG)
- Proficiency/ Currency
- Crew Workload/ Task Saturation
- Sustained/ Continuous Operations (work- rest cycles)
- Psychophysical Stress Factors
- In Flight Distractions (emergency)
- Thermal stress from flight equipment (Chemical Protective Ensemble, Anti-exposure Suit)

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Appendix E: Proposed SD mishap or incident investigation annex

Mishap or incident Identification	....

Use the following definitions for completion of this annex.

Spatial disorientation

"...when the aviator fails to sense correctly the position, motion or attitude of his aircraft or of himself within the fixed coordinate system provided by the surface of the earth and the gravitational vertical, or misperceives the position, motion or attitude of his aircraft relative to another aircraft...".

Contact with an obstacle known to be present - but erroneously judged to be sufficiently separated from the aircraft is to be included as spatial disorientation. Contact with an obstacle whose presence was simply unknown is not considered spatial disorientation, unless it is associated with other manifestations.

"Geographic disorientation" (or getting lost) is to be specifically excluded.

Role of SD in the mishap or incident (question 3)

Major	All other contributory factors would normally have been overcome without mishap.
Contributory	Other contributory factors would have led to a mishap, but SD made the accident sequence more difficult to deal with or the outcome more severe.
Incidental	SD occurred but did not affect the outcome.

USE THE SPACE BELOW EACH QUESTION FOR COMMENTS
(or continue on a blank sheet quoting the question number)

1. Could Spatial Disorientation be a factor in this mishap or incident? (Circle one)

a. -- Yes
b. -- No (If No stop here)

GO TO QUESTION 2

2. Was there more than one aircrew or aircraft involved in mishap or incident? (Circle one)

a. -- Yes (complete a separate SD annex for each aircrew with flight control)
b. -- No

GO TO QUESTION 3

3. What was the role of Spatial Disorientation in this mishap or incident? (see definitions)
(Circle one **ONLY**)

a. -- The major factor in this mishap or incident

b. -- a contributory factor leading up to this mishap or incident

c. -- only an incidental occurrence to this mishap or incident

GO TO QUESTION 4

4. Do you feel this aircrew may have **misperceived**: (choose as many as applicable, and check YES, MAYBE or NO for each)

a. -- altitude (with respect to terrain) Yes☐ Maybe☐ No☐
comments ....

b. -- speed Yes☐ Maybe☐ No☐
comments ....

c. -- vertical velocity (climb or descent) Yes☐ Maybe☐ No☐
comments ....

d. -- **roll angle** Yes☐ Maybe☐ No☐
comments ....

e. -- **pitch angle** Yes☐ Maybe☐ No☐
comments ....

f. -- **angle of attack** Yes☐ Maybe☐ No☐
comments ....

g. -- **yaw** Yes☐ Maybe☐ No☐
comments ....

h. -- **heading** Yes☐ Maybe☐ No☐
comments ....

i. -- **power** Yes☐ Maybe☐ No☐
comments ....

j. -- **flight path** Yes☐ Maybe☐ No☐
comments ....

k. -- **clearance from ground obstacles** Yes☐ Maybe☐ No☐
comments ....

l. -- **clearance from the other aircraft** Yes☐ Maybe☐ No☐
comments ....

m. -- **other** (please specify and elaborate here)
comments ....
....
....

GO TO QUESTION 5

5. How would you classify the Spatial Disorientation that played a role in this mishap or incident? (circle one **ONLY**)

a. Type I = unrecognized

b. Type II = recognized

c. Unknown or Other (e.g. physiological incapacitation), please elaborate here:

....

....

GO TO QUESTION 6

6. If possible, please estimate the duration (in seconds) in which the aircrew might have been disoriented.

....

....

GO TO QUESTION 7

7. Before the accident were there attentional/cognitive distracting factors from:

a. within the cockpit (check one) Yes☐ Maybe☐ No☐

If Yes or Maybe, describe ....

....

b. outside the cockpit (check one) Yes☐ Maybe☐ No☐

If Yes or Maybe, describe ....

....

GO TO QUESTION 8

8. Please identify which of the following factors may have contributed to the aircrew's misperception. (Check as many (Yes or Maybe) as appropriate and provide a narrative after each item)

Cognitive

a. Task Saturation Yes☐ Maybe☐
comments..
....

b. Channelized attention (e.g. fascination) Yes☐ Maybe☐
comments..
....

c. Distraction Yes☐ Maybe☐
comments..
....

d. Boredom Yes☐ Maybe☐
comments..
....

e. Fatigue Yes☐ Maybe☐
comments..
....

f. Communication failure Yes☐ Maybe☐
comments..
....

g. Decision making error Yes☐ Maybe☐
comments..
....

h. Other (please specify and elaborate) Yes☐ Maybe☐
comments..
....

GO TO QUESTION 9

9. Please identify which of the following factors may have contributed to the aircrew's misperception. (Check as many (Yes or Maybe) as appropriate and provide a narrative after each item)

Perceptual-motor

a) Visual Illusions

(1) false horizon Yes☐ Maybe☐
comments..
....

(2) illusory motion (e.g. autokinesis, climb from downwash etc.)
Yes☐ Maybe☐
comments..
....

(3) misjudgement of terrain height/slope Yes☐ Maybe☐
comments..
....

(4) misjudgement of runway height/slope Yes☐ Maybe☐
comments..
....

(5) weather-induced (e.g. whiteout, brownout) Yes☐ Maybe☐
comments..
....

(6) aircraft-induced (e.g. canopy reflections) Yes☐ Maybe☐
comments..
....

(7) Other (please specify and elaborate) Yes☐ Maybe☐
comments..
....

........Continued on next page.....

b) Vestibular Illusions

(1) linear acceleration illusion (e.g. Somatogravic, G-excess)

Yes☐ Maybe☐

comments...

....

(2) angular acceleration illusion (Somatogyral illusion, Coriolis, graveyard spin)

Yes☐ Maybe☐

comments...

....

(3) combined linear-angular (graveyard spiral)

Yes☐ Maybe☐

comments...

....

c) Other Perceptual-motor effects (please specify and elaborate)

Yes☐ Maybe☐

comments...

....

GO TO QUESTION 10

10. Please identify which of the following factors may have contributed to the aircrew's misperception. (Check as many (Yes or Maybe) as appropriate and provide a narrative after each item)

Information Displays

a. HEAD-DOWN DISPLAY

(1) Specify display ....

(2) Location of display ....

(3) Visual limitation of display Yes☐ Maybe☐
comments..
....

(4) Failed to attend symbology Yes☐ Maybe☐
comments..
....

(5) Misinterpreted symbology Yes☐ Maybe☐
comments..
....

(6) Critical information not presented Yes☐ Maybe☐
comments..
....

(7) Misleading information presented Yes☐ Maybe☐
comments..
....

(8) Other (please specify and elaborate) Yes☐ Maybe☐
comments..
....

........Continued on next page.....

b. HEAD-UP DISPLAY

(1) Specify display ....

(2) Location of display ....

(3) Visual limitation of display Yes☐ Maybe☐
comments..
....

(4) Failed to attend symbology Yes☐ Maybe☐
comments..
....

(5) Misinterpreted symbology Yes☐ Maybe☐
comments..
....

(6) Critical information not presented Yes☐ Maybe☐
comments..
....

(7) Misleading information presented Yes☐ Maybe☐
comments..
....

(8) Other (please specify and elaborate) Yes☐ Maybe☐
comments..
....

........Continued on next page.....

c. HELMET-MOUNTED DISPLAY

(1) Specify display ....

(2) Visual limitation of display Yes☐ Maybe☐
comments...
....

(3) Failed to attend symbology Yes☐ Maybe☐
comments...
....

(4) Misinterpreted symbology Yes☐ Maybe☐
comments...
....

(5) Critical information not presented Yes☐ Maybe☐
comments...
....

(6) Misleading information presented Yes☐ Maybe☐
comments...
....

(7) Other (please specify and elaborate) Yes☐ Maybe☐
comments...
....

........Continued on next page.....

d. NIGHT VISION DEVICE

(1) Specify display ....

(2) Location of display ....

(3) Visual limitation of display Yes☐ Maybe☐
comments..
....

(4) Failed to attend symbology Yes☐ Maybe☐
comments..
....

(5) Misinterpreted symbology Yes☐ Maybe☐
comments..
....

(6) Critical information not presented Yes☐ Maybe☐
comments..
....

(7) Misleading information presented Yes☐ Maybe☐
comments..
....

(8) Other (please specify and elaborate) Yes☐ Maybe☐
comments..
....

GO TO QUESTION 11

11. Were there any **training** issues identified during the accident investigation? (Check one, and if YES, please specify)

Yes☐ No☐

Specify, if YES ....
....
....
....

GO TO QUESTION 12

12. During your investigation, were any potential technological solutions identified that would have reduced the chances of an accident (or have reduced its severity)?

(Check one, and if YES, please specify)

Yes☐ No☐

(some possibilities could include: height audio warnings, injected symbology in NVDs, improved stability systems, improved standard instruments, better internal lighting, better visibility devices on aircraft, peripheral vision devices, etc)

Specify, if YES ....
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GO TO QUESTION 13

13. REMARKS: Please make additional comments or continue your narratives from above.

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THANK-YOU

Appendix F:
SD - initiatives to overcome a significant impact on rotary-wing operations

The text of a Recommendation paper prepared by Lt Col Malcolm Braithwaite addressed to the Commander of the U.S. Army Safety Center and Dean of the U.S. Army School of Aviation Medicine following the symposium is reproduced below.

Introduction

Several recent studies at the U.S. Army Aeromedical Research Laboratory (USAARL) and the U.S. Army Safety Center (USASC) have highlighted the significant contribution of Spatial Disorientation (SD) to helicopter accidents. In the U.S. Army the cost can be approximated at $58M and 14 lives each year. Following some local training initiatives by USAARL and the U.S. Army School of Aviation Medicine (USASAM), the first Triservice Symposium on Spatial Disorientation in Rotary Wing Operations was held from 24 September 1996 through 26 September 1996 at USASAM. This symposium sought to address three main areas: the seriousness of the SD hazard; current methods to control the hazard; and the associated safety and risk management concerns.

The symposium was considered to be a success in raising the awareness of the impact of SD on rotary wing flying operations in the aeromedical and safety communities of the services. It was clear that SD imposes a particular hazard to rotary wing operations which differs in many respects to that experienced by fixed wing operators. There was unanimous agreement that initiatives to overcome the problem must be made.

In order to maintain the impetus established by the symposium and secure funding for the various initiatives, this memorandum details the important factors and makes recommendations for future activity in the area. Work is required in the following four areas which will be covered separately: Education, Training, Research, Equipment. Control factors are annotated according to whether the approach should be solely directed towards the U.S. Army, or on a triservice basis.

Coordination of effort

Under the auspices of the Triservice Aeromedical Research Panel (TARP), a Triservice Working Group (TWG) on Situational Awareness and Spatial Disorientation already addresses coordination on research issues on this area. With a small addition to its membership (i.e. representatives from training and operational authorities) this organization can be readily tasked to coordinate the triservice effort. It is recommended that an SD working group be established within U.S. Army Aviation to coordinate the single service issues. A suggested membership is representatives from USASC, USAARL, USASAM, Aviation Training Brigade, and DES. This will be referred to as the Army Working Group (AWG).

Education

Now that the problem of SD has been properly uncovered, aviation commanders and aircrew need to be made aware of the potential threat that SD poses during peace and war. There are two requirements to improve the understanding of this hazard:

a. Data collection to accurately define and monitor the size of the problem.

b. Dissemination of the lessons learned from accident analysis, research and training on a regular basis.

Data collection

An accurate record of the number of accidents in which SD is implicated is required, so that comparison of accidents involving SD with other accidents can be made in order to determine particular patterns associated with SD accidents. Thence, areas for further research and application of training controls and technological solutions can be made. To achieve this a standardization of the data collection on accidents in which SD involved is required.

a. U.S. Army Initiatives. The USAARL studies have coded helicopter accidents from 1987 through 1995 in a discrete database. Those accidents should now be similarly annotated by the Safety Center Surgeon in the USASC database, and similar methods used for future accidents.

b. Triservice Initiatives. Conformity in all accident classification cannot be expected between the services. Therefore, it is recommended that the aeromedical evaluation of the accident is augmented by "fielding" the proposed SD mishap appendix. The symposium agreed that this was feasible and that flight surgeons are probably the most appropriate personnel to complete the appendix. Once approved by the Accident Investigation Board, the appendix would be sent to that service's Safety Center Surgeon for collation. This action need not affect any internal classification in the individual Safety Centers, and should be coordinated by the TWG.

Lessons learned

The sustainment of education can be readily achieved by regular refresher training and briefings at all levels from triservice symposia to unit briefings.

a. U.S. Army Initiatives. AWG to consider and make recommendations.

b. Triservice Initiatives. TWG to consider and make recommendations.

Training

Training was considered in depth at the symposium and each service has its own initiatives. Although the syllabus for training aircrew in SD is covered generically in a Standard NATO Agreement (STANAG) and a proposed Air Standardization Coordination Committee Air Standard, this issue needs to be fine tuned.

U.S. Army Initiatives

The AWG should consider the following issues and make recommendations.

a. Ground-based lectures. A review of the ground-based SD training has already been done by USAARL, and USASAM are re-writing their lesson plans based on the recommendations of that review. This should be achieved by 31 December 1996. A program for refresher training should be instituted and both instrument flying training and crew coordination training augmented with reference to the nature of SD in helicopter operations.

b. Ground-based demonstration of illusions. The equipment and a specific helicopter profile for the demonstration of disorienting illusions does not exist.

c. Airborne demonstration. There was an enthusiastic response from the symposium on the SD demonstration sortie as flown by the British Army. This sortie is now being assessed by USAARL to determine whether it will be an effective adjunct in training aircrew in SD. A report is expected by 31 Mar 97. It is hoped that aviation training authorities will agree to a feasibility study on the inclusion of this demonstration in initial and refresher flight training.

d. Training to overcome SD in flight. This is done by most services but on an ad hoc basis. The training should be formalized in both simulators and in flight with standardized learning objectives established in the curriculum.

Triservice Initiatives

Agreement should be sought on the initial and refresher training in SD in all the above areas for rotary wing pilots and flight surgeons of all services. USASAM has offered to coordinate this under the auspices of a Working Group on Aeromedical Training. TWG also to consider and make recommendations.

Research

Research into SD needs to be of definable benefit to the operational community. Now that the problem of SD has been properly uncovered, direct application of research to save lives, money and operational efficiency can be achieved. It is not appropriate in this memorandum to exhaustively list the areas in which research is required but the generic aims are listed below:

<u>Near term</u>

a. Standardization of Terminology. Formally agree to use the definition of SD as endorsed by the TWG, so that direct comparison between the services' experience can be made. Seek agreement on a definition of Situational Awareness especially with respect to the position of SD as a subset of SA.

b. Evaluate the applicability of improved instrumentation using currently available technology.

<u>Mid term</u>

a. Develop models of spatial orientation in specific operational environments so that the hazard and risk can be better defined and training controls applied.

b. Assess the low risk and low cost technological developments to assist maintenance and re-establishment of orientation (e.g. new visual, vibrotactile and auditory displays).

<u>Long term</u>

a. Identify the SD controls that need to be incorporated into aircraft design specifications.

b. High risk and high cost technological developments such as Virtual Reality displays.

It is clear that the research detailed above is applicable to rotary wing operations of all services. Coordination of the research to prevent duplication of effort already occurs through the TWG, but so that research can be properly funded, the objectives to be achieved must be stated by the operational community and the research organizations formally tasked. This is a single service issue.

U.S. Army Initiatives

Recommend the AWG coordinate research efforts with appropriate Army agencies. Further recommend appropriate army agencies task USAARL to perform research as detailed above.

Triservice Initiatives

Coordination of research effort to continue through the TWG.

Equipment

The USAARL analysis of U.S. Army helicopter accidents include recommendations to perform further research and install equipment to help both prevent and overcome SD. These are applicable to triservice helicopter operations and include the following items:

a. Audio warnings on all radar altimeters.

b. Flight data recorders.

c. Pursue the introduction of the NVG "HUD".

d. Continue the development of "hover locks" to aid station keeping and reduce pilot workload.

e. Develop a helicopter-specific instrument panel to include the provision of hover and drift information.

f. Identification of devices such as simulators that are best capable of simulating SD that could be used both as demonstrators and trainers.

U.S. Army Initiatives

A cost benefit analysis is required to convince DOD to fund incorporation of devices in Army aircraft. This can be readily achieved from data contained in the USAARL study. USAARL should be specifically tasked to carry out this analysis.

Triservice Initiatives

Coordination of the research effort into this area is already performed by the TWG. This should continue.

Conclusion

The risk of the hazard of SD has a significant impact on rotary wing operational effectiveness. Controls are clearly needed and should be implemented as set out in this memorandum without delay.

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